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(12) **United States Patent**
Axelson, Jr. et al.

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(45) **Date of Patent: Aug. 30, 2016**

(54) **BONE PADS**

(71) Applicant: **Stryker Corporation**, Kalamazoo, MI (US)

(72) Inventors: **Stuart L. Axelson, Jr.**, Succasunna, NJ (US); **Donald W. Malackowski**, Schoolcraft, MI (US); **John Michael Stuart**, Rio Rancho, NM (US)

(73) Assignee: **Stryker Corporation**, Kalamazoo, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 262 days.

(21) Appl. No.: **14/195,113**

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(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
A61F 2/46 (2006.01)
A61B 17/16 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61F 2/461*** (2013.01); ***A61B 17/1604*** (2013.01); ***A61B 17/1675*** (2013.01); ***A61F 2/30771*** (2013.01); ***A61F 2/389*** (2013.01); ***A61F 2/3859*** (2013.01); *A61B 17/1615* (2013.01); *A61F 2002/30321* (2013.01); *A61F 2002/30322* (2013.01); *A61F 2002/30807* (2013.01); *A61F 2002/30827* (2013.01); *A61F 2002/30884* (2013.01); *A61F 2002/3895* (2013.01); *A61F 2002/4631* (2013.01)

(58) **Field of Classification Search**
CPC A61B 17/16; A61B 17/1604; A61B 17/1659; A61B 17/1662; A61B 17/1675; A61B 2017/1602; A61F 2/3859; A61F 2/389; A61F 2/46; A61F 2/4603–2/4614; A61F 2/4618; A61F 2002/4631
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,055,862 A * 11/1977 Farling A61F 2/38 264/122
4,550,448 A 11/1985 Kenna
(Continued)

OTHER PUBLICATIONS

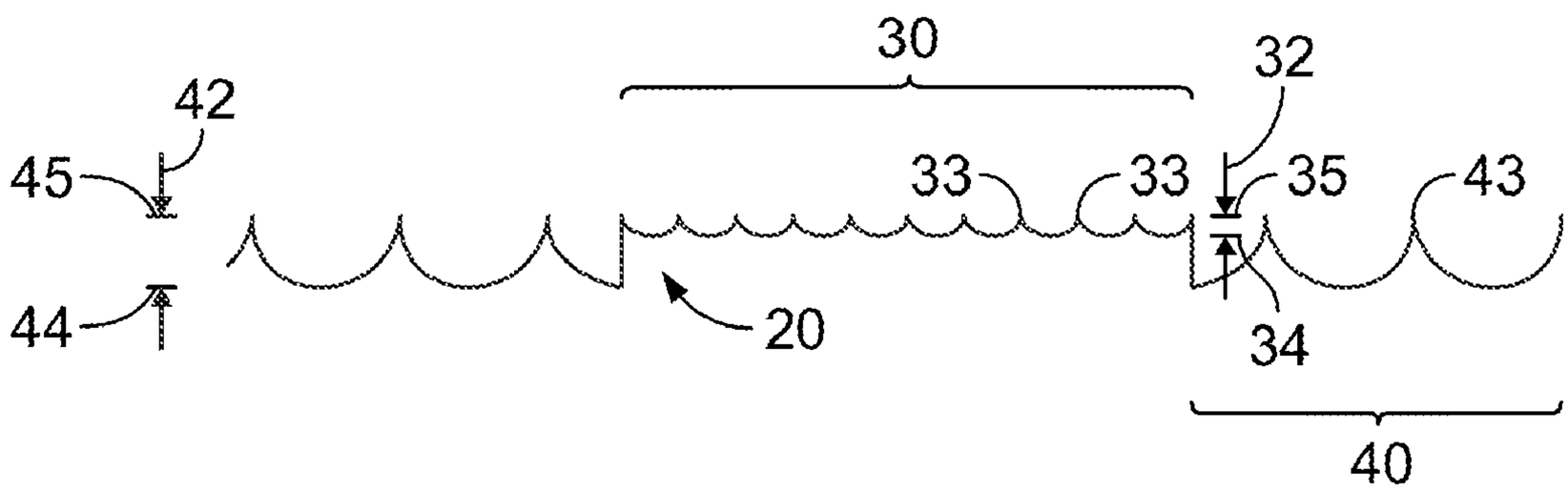
Biomet, Premier Total Knee Instrumentation, 2010-2011.
(Continued)

Primary Examiner — Christian Sevilla
Assistant Examiner — Eric S Gibson
(74) *Attorney, Agent, or Firm* — Lerner, David, Littenberg, Krumholz & Mentlik, LLP

(57) **ABSTRACT**

Disclosed herein are systems and methods for bone preparation with designed areas having accurate tolerance profiles to enable improved initial fixation and stability for cementless implants and to improve long-term bone ingrowth/ongrowth to an implant. A method of preparing a bone surface to receive a prosthetic implant thereon having an articular surface and a bone contacting surface includes resecting the bone surface at a first location to create a first resected region having a first tolerance profile with a first cross-section, resecting the bone surface at a second location to create a second resected region having a second tolerance profile with a second cross-section less dense than the first cross-section, and contacting the bone contacting surface of the prosthetic implant with the first resected region.

19 Claims, 32 Drawing Sheets



(51) **Int. Cl.**
A61F 2/38 (2006.01)
A61F 2/30 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,919,671	A *	4/1990	Karpf	A61F 2/389 623/20.3
5,092,895	A *	3/1992	Albrektsson	A61F 2/3868 623/20.3
5,207,680	A	5/1993	Dietz et al.	
5,344,423	A *	9/1994	Dietz	A61B 17/1764 606/86 R
5,474,559	A *	12/1995	Bertin	A61B 17/154 606/86 R
5,486,180	A	1/1996	Dietz et al.	
5,560,096	A *	10/1996	Stephens	A61F 2/3859 29/527.6
5,593,411	A	1/1997	Stalcup et al.	
5,601,563	A	2/1997	Burke et al.	
5,634,927	A *	6/1997	Houston	A61B 17/1735 606/79
5,768,134	A *	6/1998	Swaelens	A61C 13/0004 433/201.1
5,853,415	A	12/1998	Bertin et al.	
6,102,954	A *	8/2000	Albrektsson	A61B 17/8605 623/20.32
6,217,617	B1 *	4/2001	Bonutti	A61B 17/8802 623/20.14
6,676,669	B2	1/2004	Charles et al.	
6,702,805	B1	3/2004	Stuart	
6,723,106	B1	4/2004	Charles et al.	
7,458,991	B2	12/2008	Wang et al.	
7,537,664	B2	5/2009	O'Neill et al.	
7,674,426	B2	3/2010	Grohowski, Jr.	
7,695,519	B2 *	4/2010	Collazo	A61F 2/389 623/20.15
7,727,239	B2 *	6/2010	Justin	A61B 17/1615 606/86 R
7,867,236	B2 *	1/2011	Hodorek	A61B 17/157 606/84
7,892,243	B2	2/2011	Stuart	
7,896,923	B2 *	3/2011	Blackwell	A61F 2/30721 623/20.21
7,927,335	B2 *	4/2011	Deffenbaugh	A61B 17/1617 606/87
8,211,113	B2 *	7/2012	Brown	A61B 17/1615 606/96
8,506,645	B2 *	8/2013	Blaylock	A61B 17/1764 623/23.22
8,535,385	B2 *	9/2013	Hanssen	A61F 2/30 623/23.19
8,556,908	B2 *	10/2013	Nycz	A61B 17/1764 606/87
8,753,401	B2 *	6/2014	Dee	A61F 2/30756 623/16.11
8,764,760	B2 *	7/2014	Metzger	A61B 17/155 606/88
8,852,195	B2 *	10/2014	Justin	A61B 17/1675 606/87
8,945,222	B2 *	2/2015	Linares	A61F 2/30 623/17.11
9,138,259	B2 *	9/2015	Maxson	A61B 17/1739
2002/0022889	A1 *	2/2002	Chibrac	A61F 2/3603 623/18.11
2002/0107573	A1 *	8/2002	Steinberg	A61B 17/00234 623/17.12
2002/0183760	A1 *	12/2002	McGovern	A61B 17/1764 606/88
2003/0005786	A1	1/2003	Stuart et al.	
2003/0130665	A1 *	7/2003	Pinczewski	A61B 17/154 606/88
2005/0143831	A1 *	6/2005	Justin	A61B 17/157 623/20.17
2005/0192588	A1 *	9/2005	Garcia	A61B 17/155 606/88
2006/0089621	A1 *	4/2006	Fard	A61B 17/1615 606/1
2006/0095135	A1 *	5/2006	Kovacevic	A61F 2/389 623/20.32
2006/0147332	A1	7/2006	Jones et al.	
2006/0228247	A1	10/2006	Grohowski	
2006/0276796	A1 *	12/2006	Creger	A61B 17/1767 606/79
2007/0005142	A1 *	1/2007	Rhodes	A61F 2/389 623/20.32
2007/0100462	A1 *	5/2007	Lang	A61F 2/30942 623/20.29
2007/0299532	A1 *	12/2007	Rhodes	A61F 2/389 623/20.32
2008/0154270	A1 *	6/2008	Haines	A61B 17/155 606/88
2008/0202274	A1	8/2008	Stuart	
2008/0234683	A1 *	9/2008	May	A61B 17/17 606/87
2008/0275452	A1 *	11/2008	Lang	A61B 17/15 606/88
2009/0076605	A1 *	3/2009	Linares	A61F 2/32 623/14.12
2009/0198340	A1 *	8/2009	Cloutier	A61B 17/1764 623/20.35
2009/0280179	A1	11/2009	Neumann et al.	
2009/0287222	A1 *	11/2009	Lee	A61B 17/1615 606/130
2009/0318584	A1	12/2009	Speitling et al.	
2010/0076441	A1 *	3/2010	May	A61B 17/1675 606/79
2010/0082034	A1 *	4/2010	Remia	A61B 17/8685 606/88
2010/0121459	A1	5/2010	Garigapati et al.	
2010/0145343	A1 *	6/2010	Johnson	A61B 17/025 606/85
2010/0268249	A1	10/2010	Stuart	
2010/0268250	A1	10/2010	Stuart et al.	
2010/0275718	A1	11/2010	Stuart et al.	
2011/0106093	A1 *	5/2011	Romano	A61B 17/155 606/88
2012/0330429	A1 *	12/2012	Axelson, Jr.	A61F 2/30771 623/20.19
2014/0012267	A1 *	1/2014	Sikora	A61F 2/3859 606/88
2014/0128874	A1 *	5/2014	Gibson	A61B 17/1746 606/79
2014/0257293	A1 *	9/2014	Axelson, Jr.	A61B 17/1675 606/79
2014/0277544	A1 *	9/2014	Viscogliosi	A61B 17/3472 623/20.32
2014/0277549	A1 *	9/2014	Ell	A61F 2/3859 623/20.35
2015/0164648	A1 *	6/2015	Lizak	A61F 2/3868 623/20.29
2016/0008136	A1 *	1/2016	Jones	A61F 2/389 623/20.17

OTHER PUBLICATIONS

Zimmer, Cruciate Retaining and Revision Instrumentation Surgical Technique, 2002, 2005, 2008, 2011.

Zimmer, Gender Solutions Patello-Femoral Joint (PFJ) System, 2008, 2009.

* cited by examiner

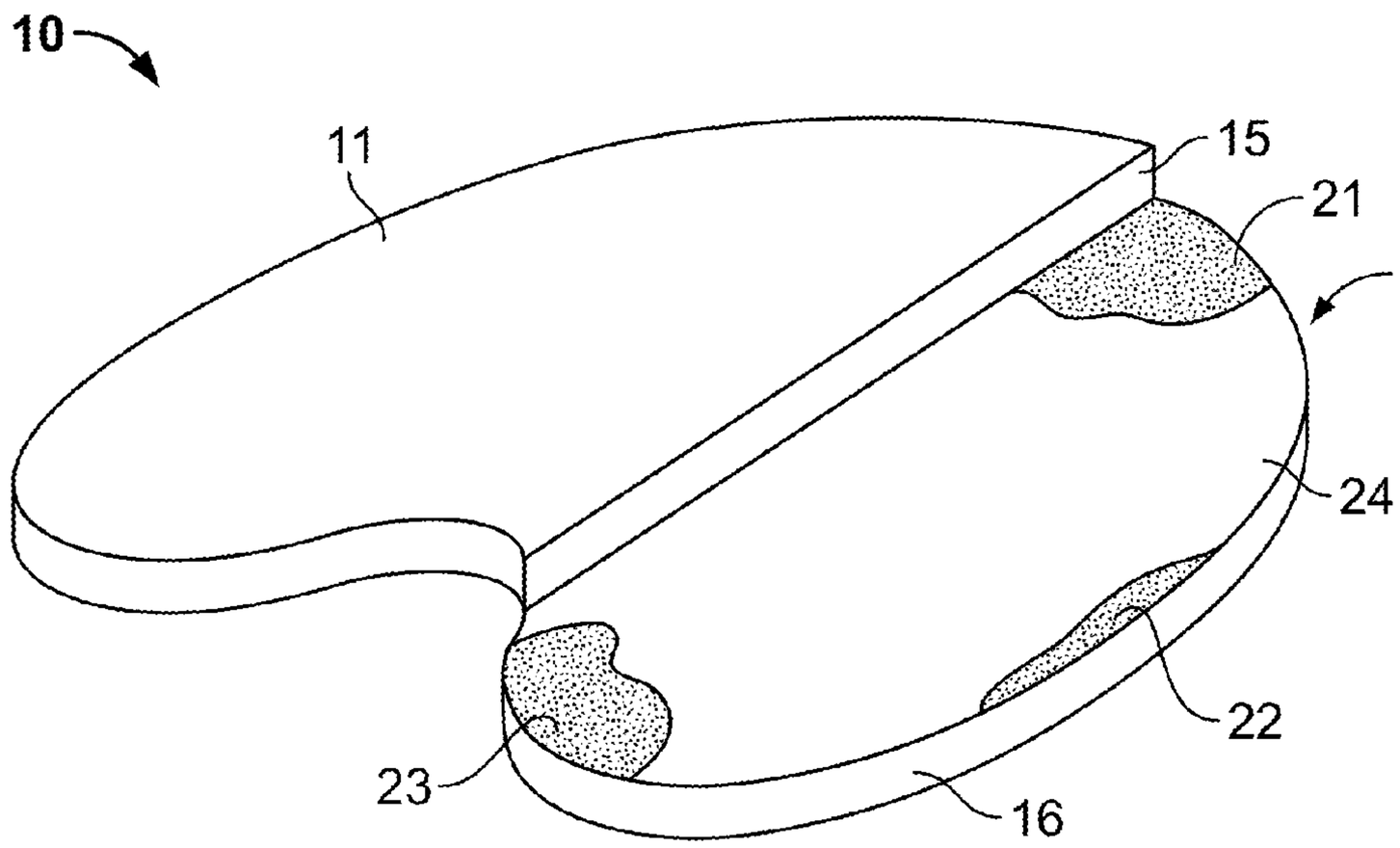


FIG. 1

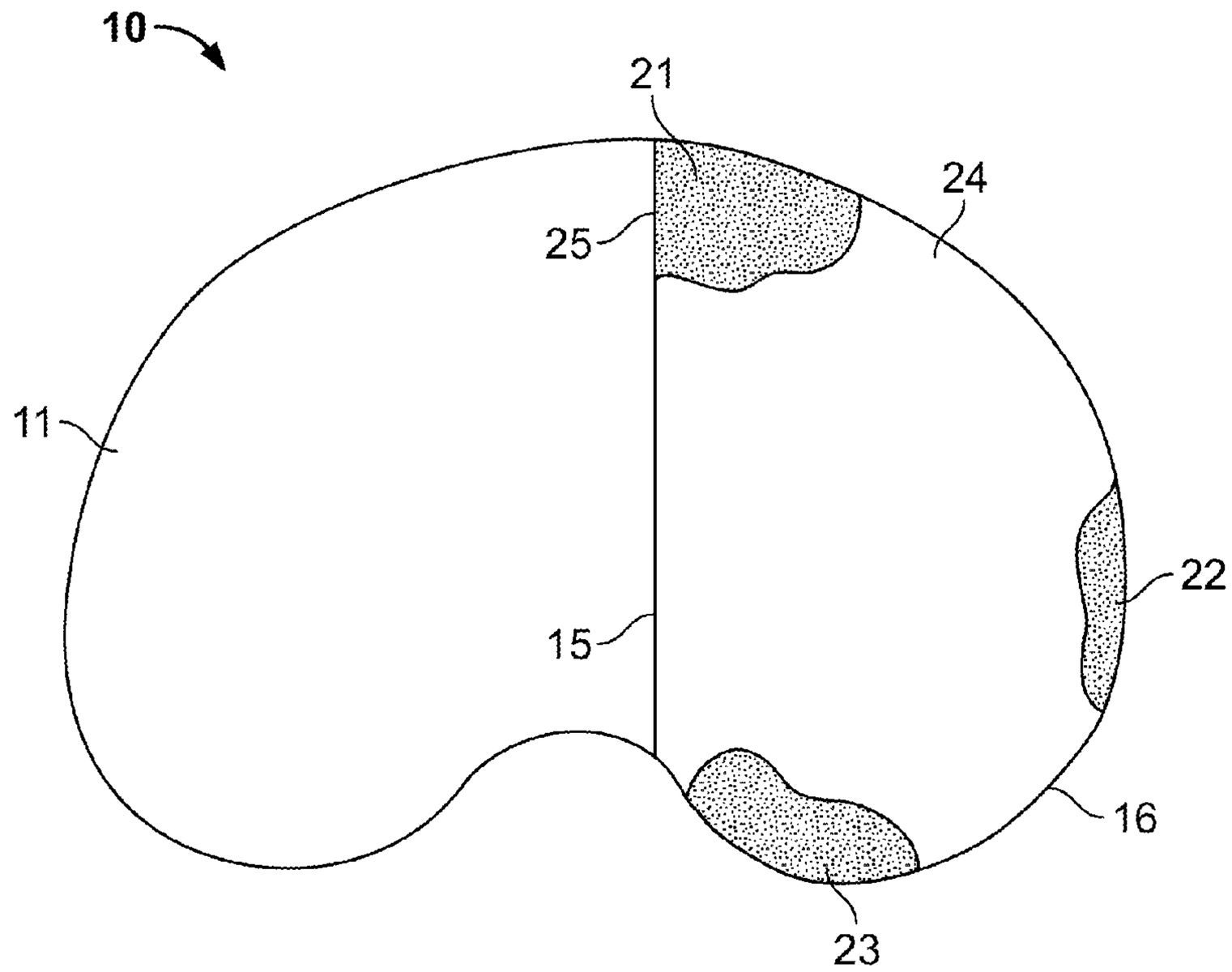


FIG. 2

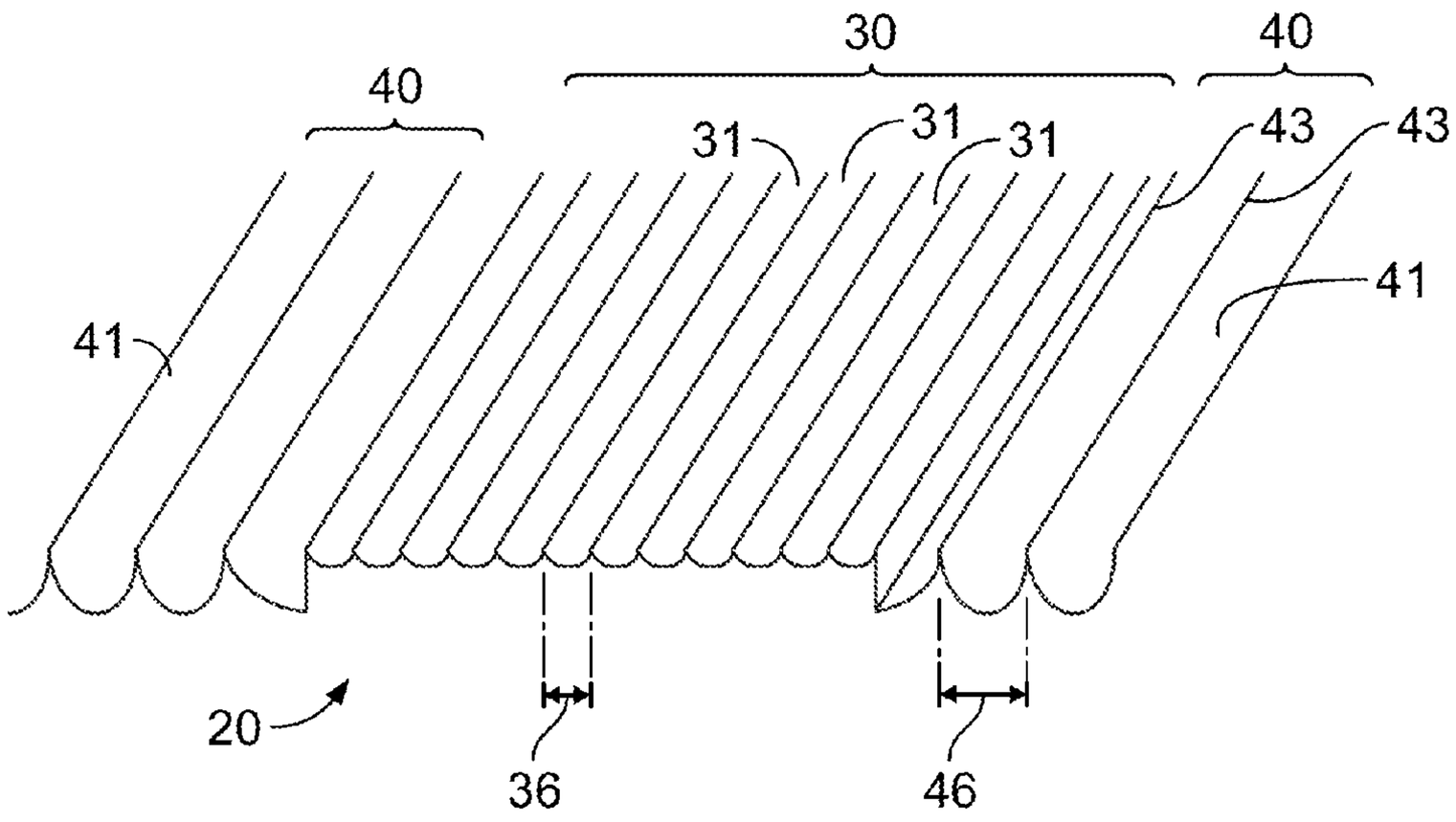

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FIG. 3

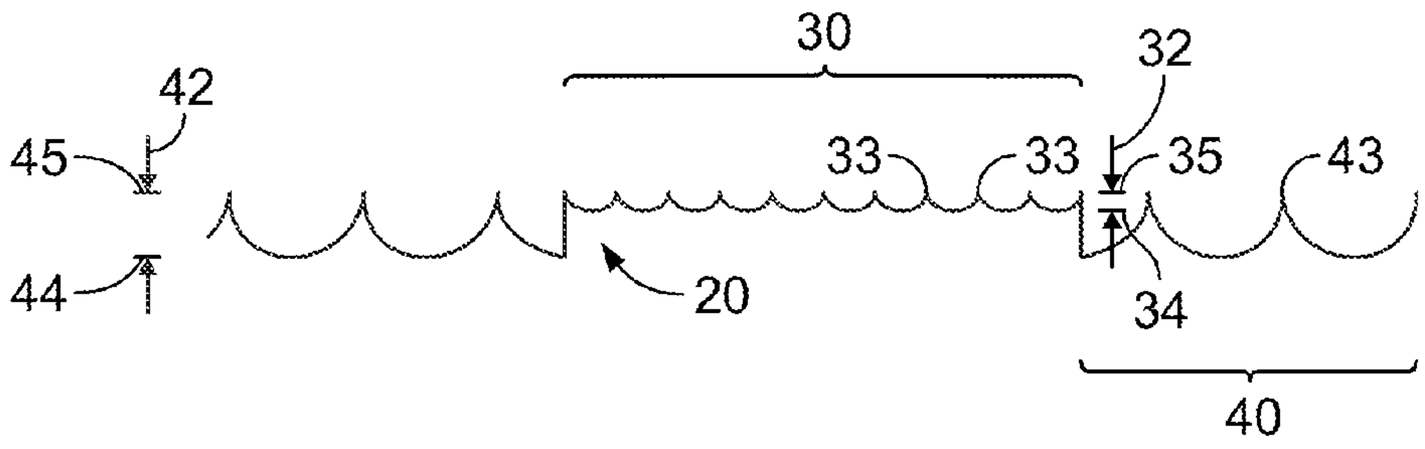
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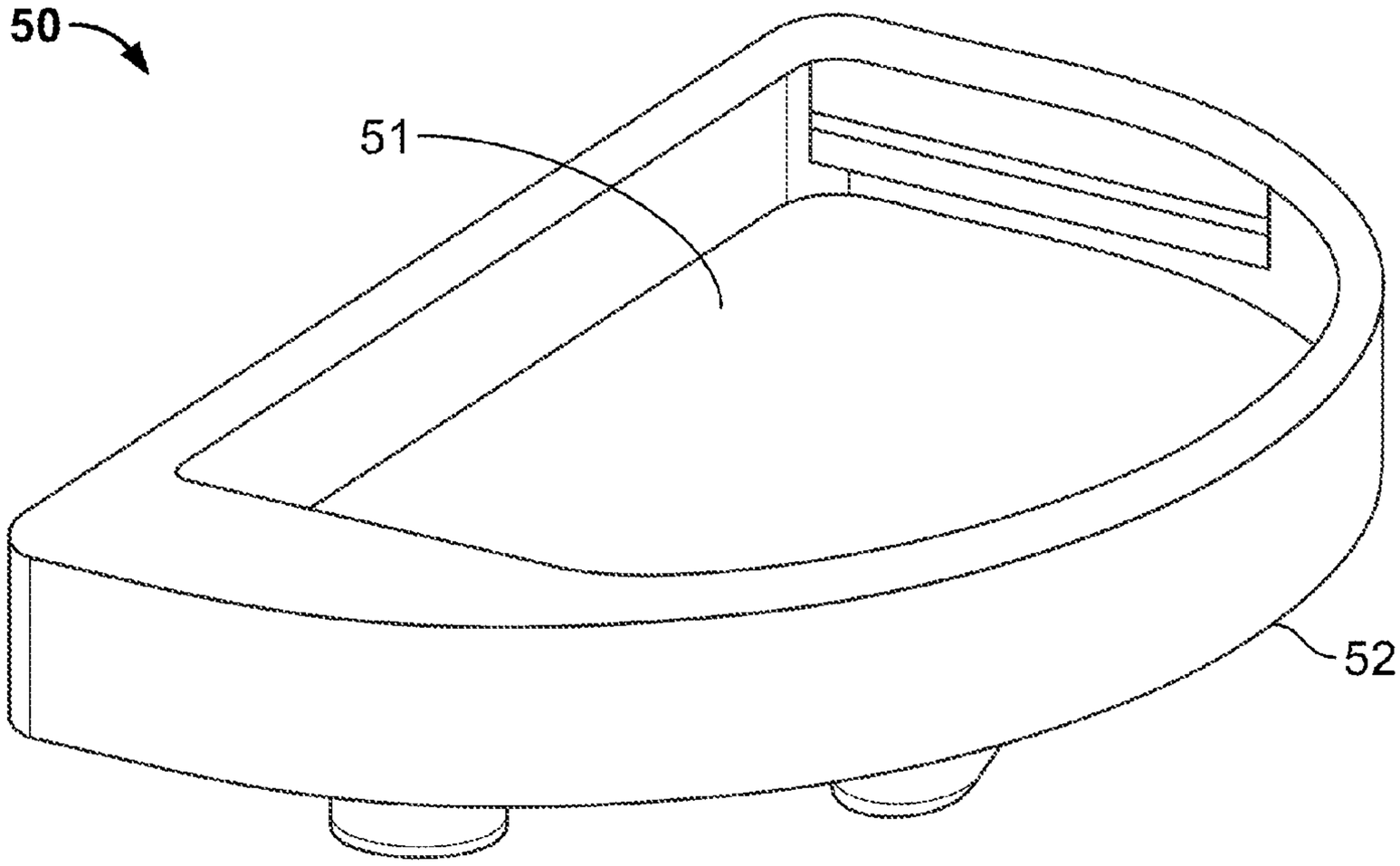
FIG. 4



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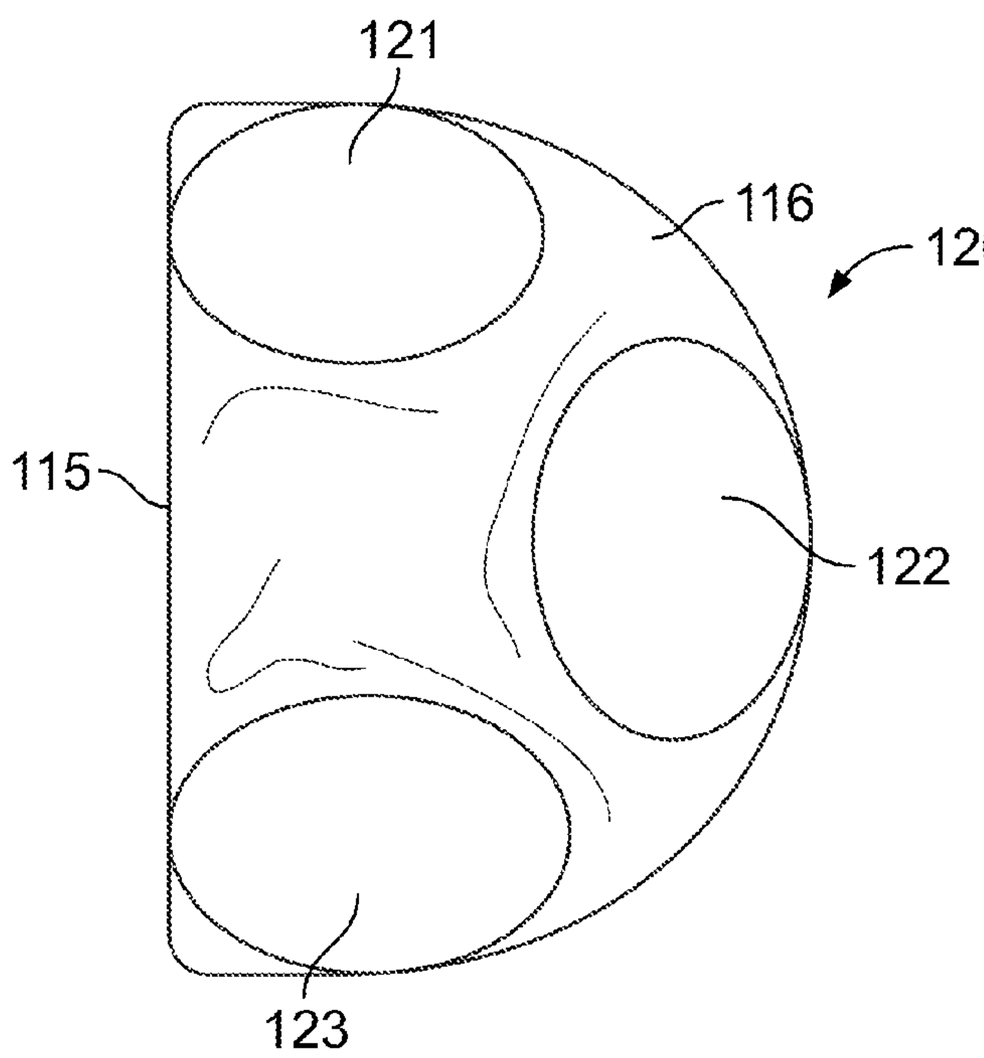

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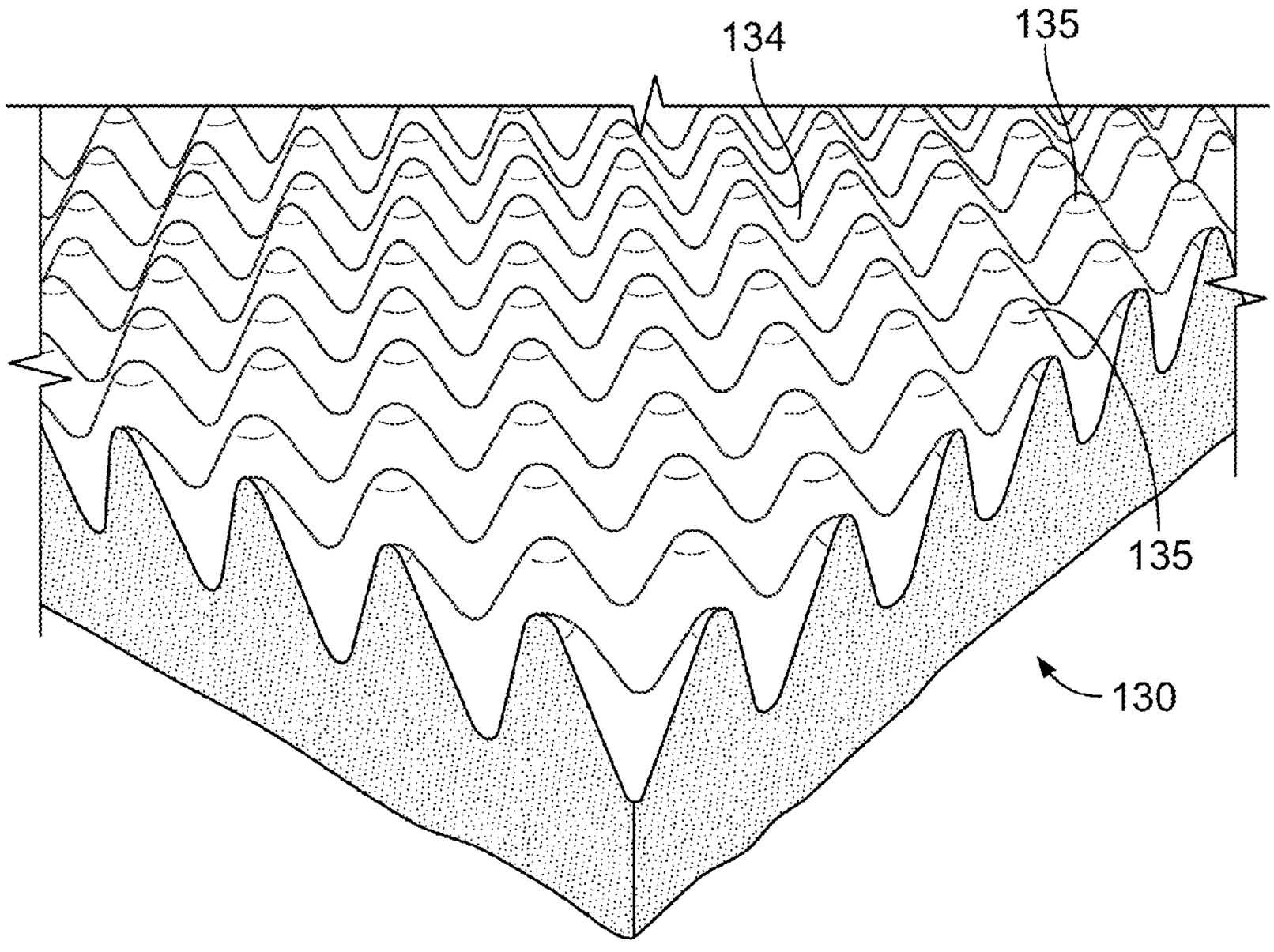

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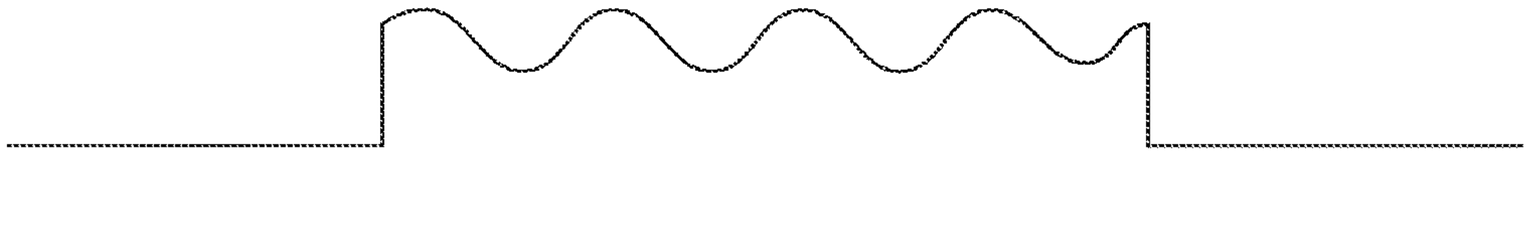

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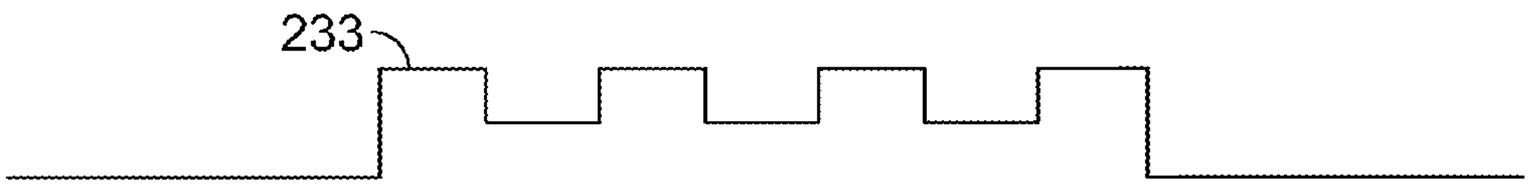

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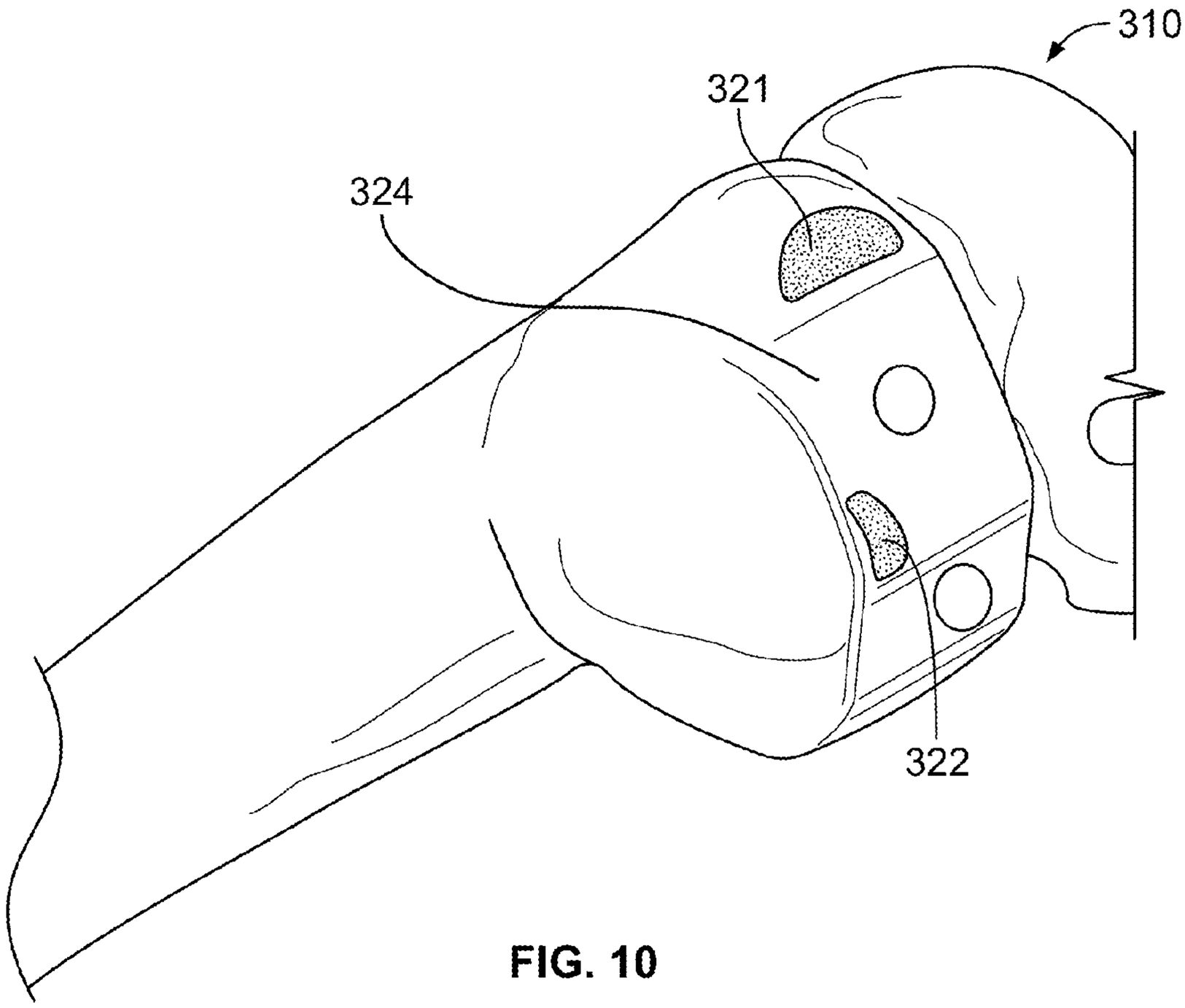

FIG. 10

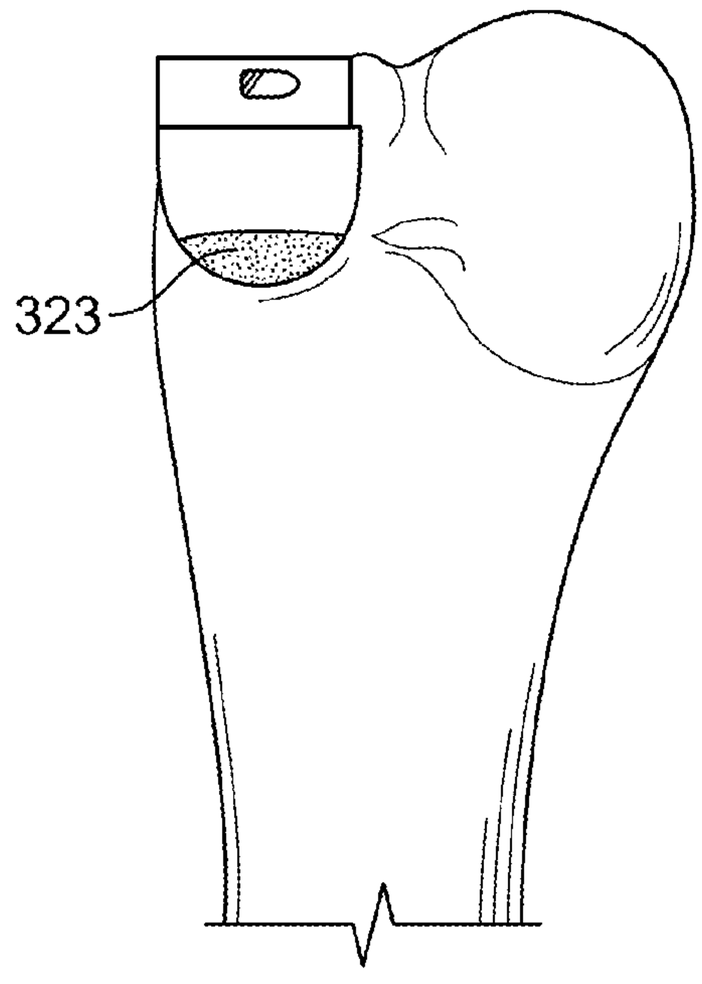

FIG. 11

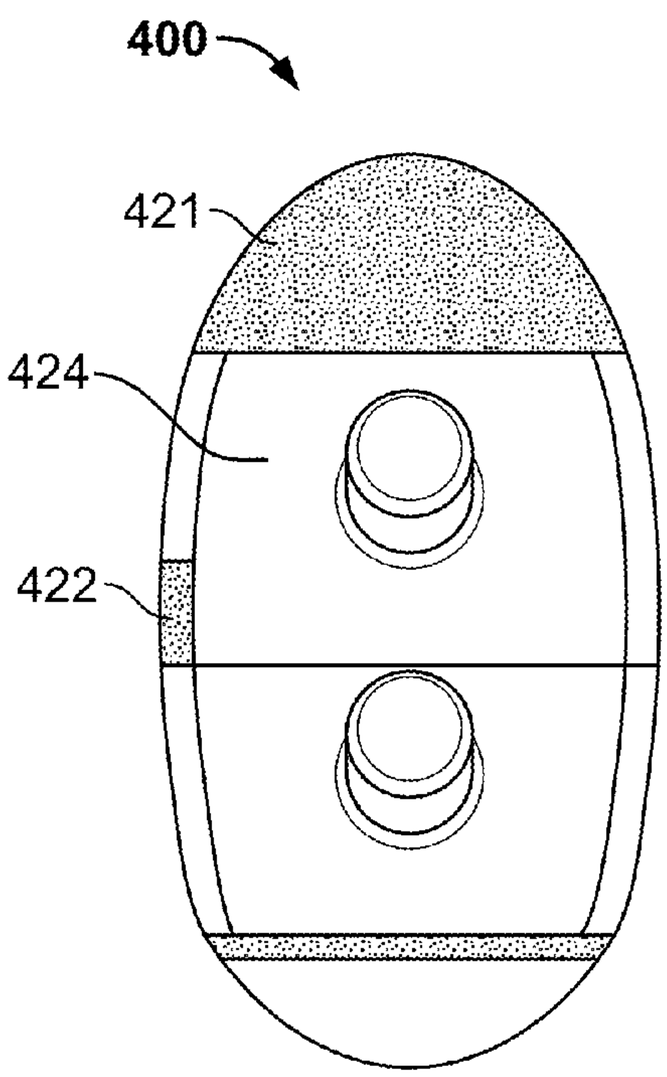

FIG. 12

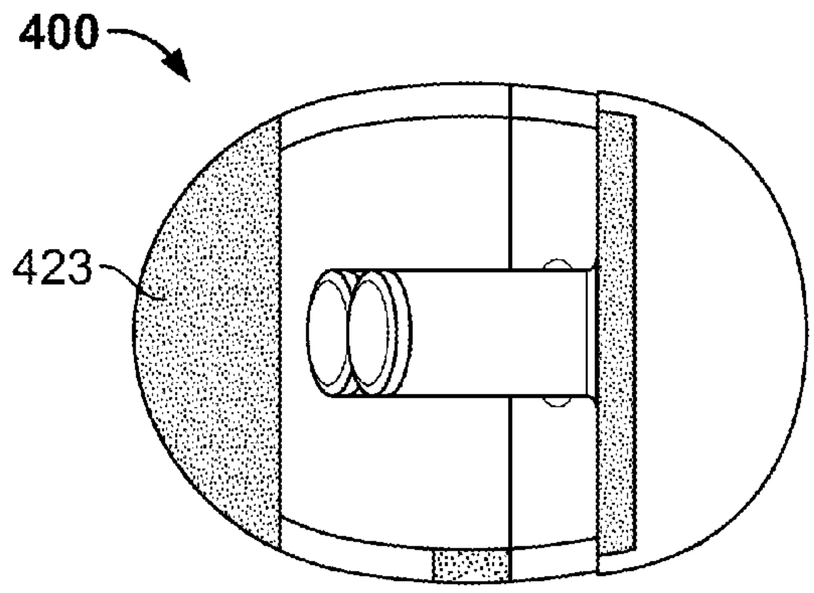

FIG. 13

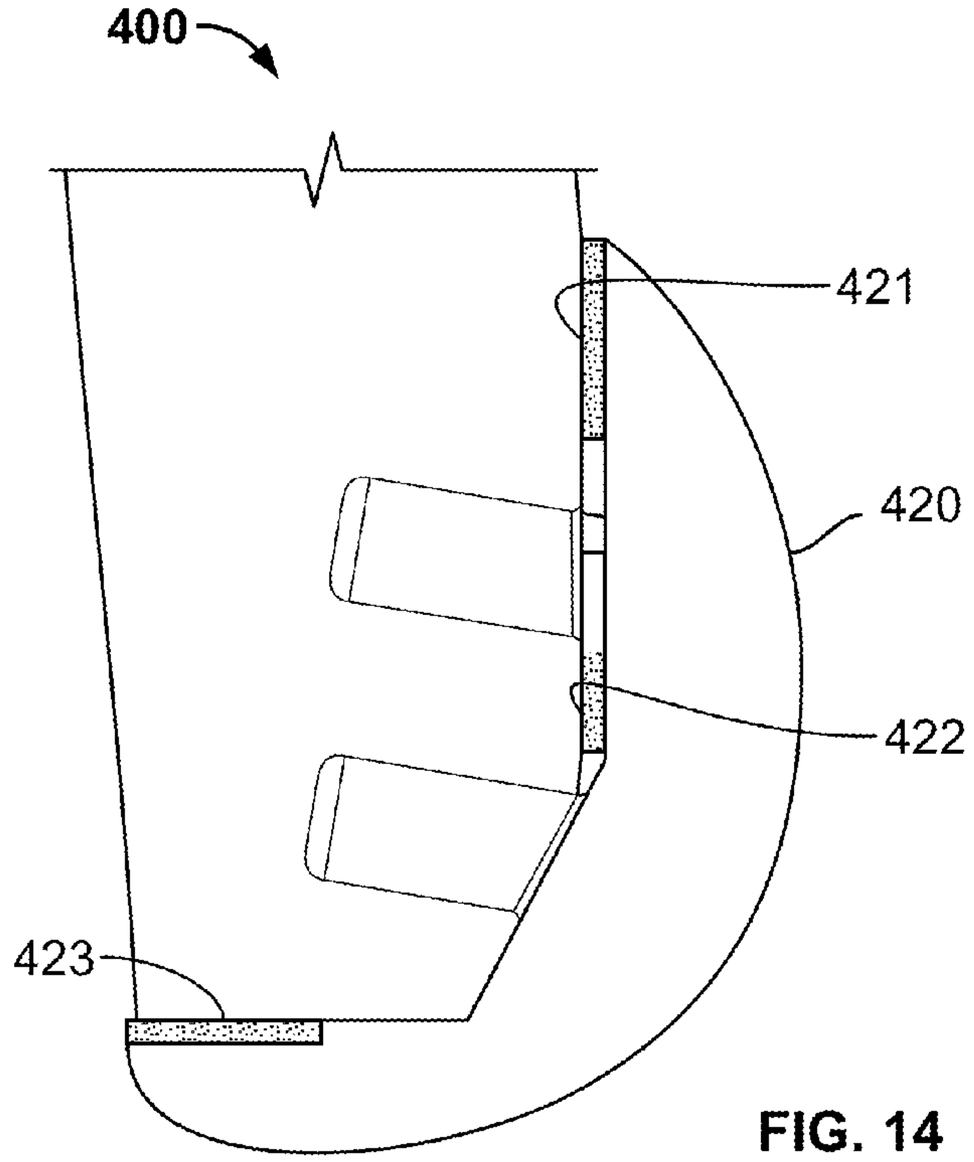

FIG. 14

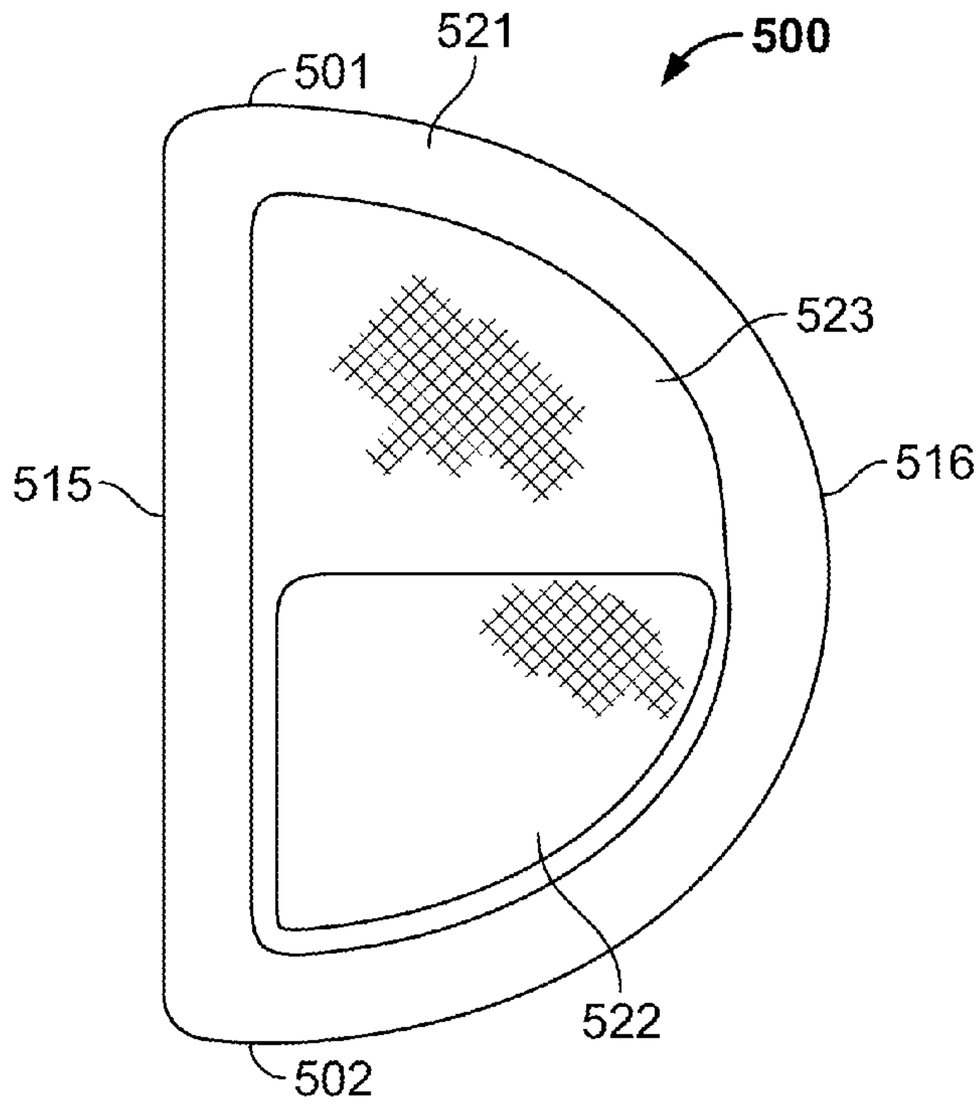

FIG. 15

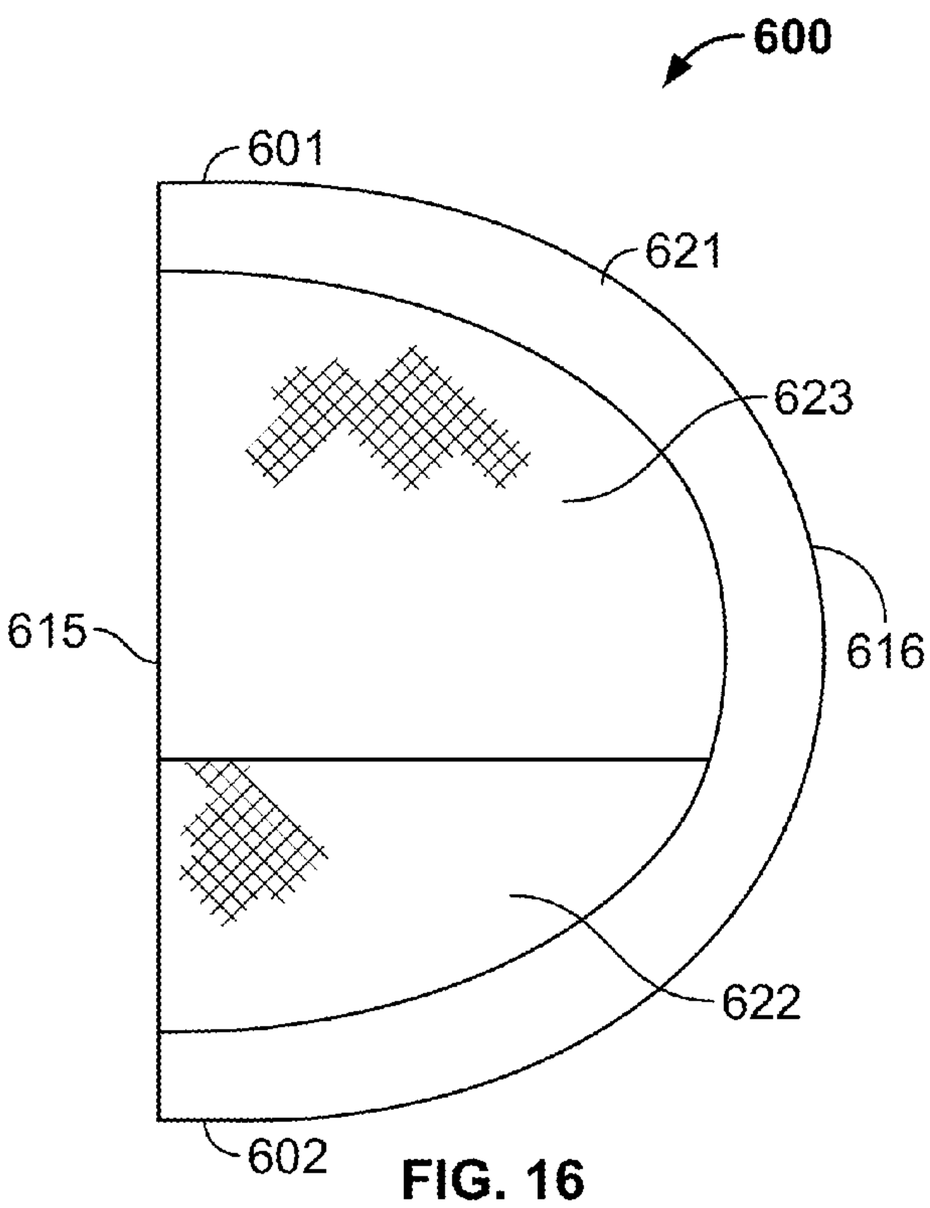

FIG. 16

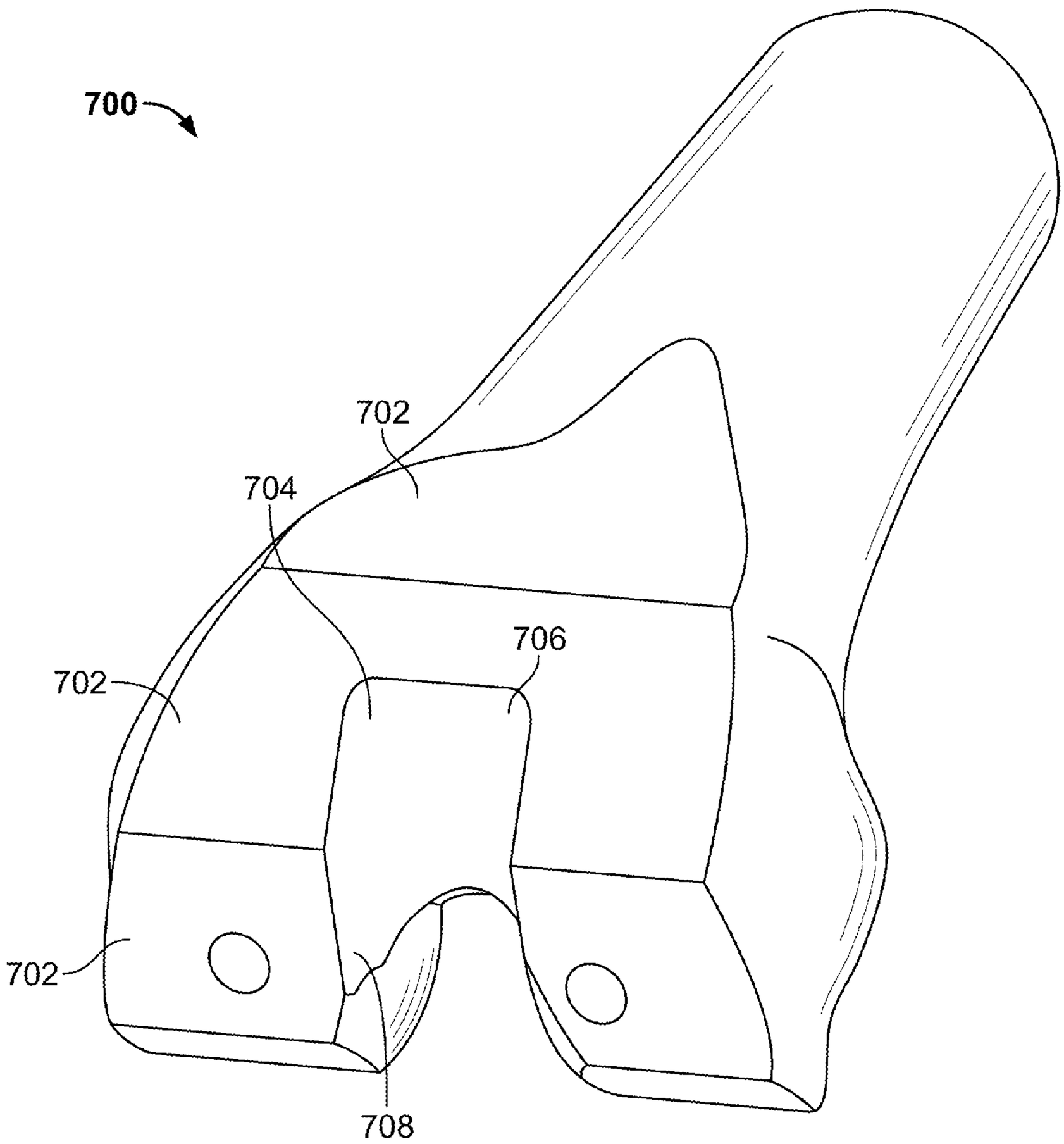

FIG. 17

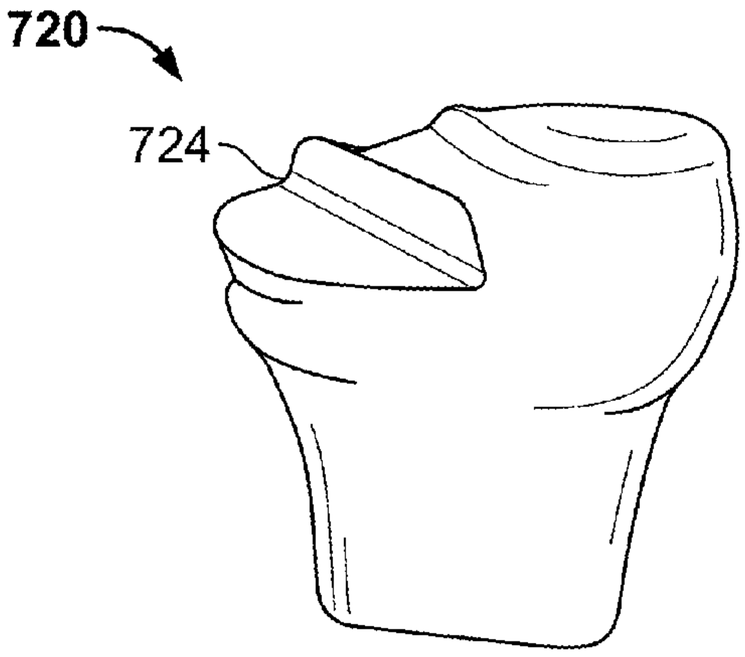

FIG. 18A

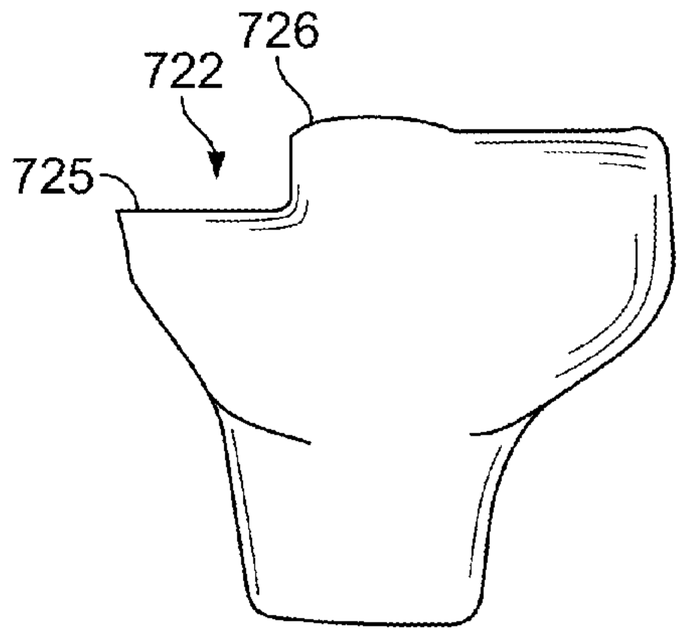

FIG. 18B

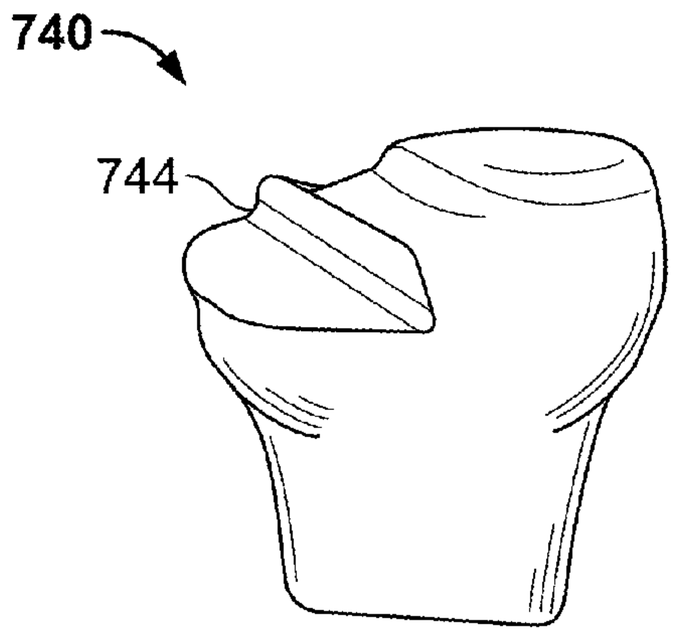

FIG. 19A

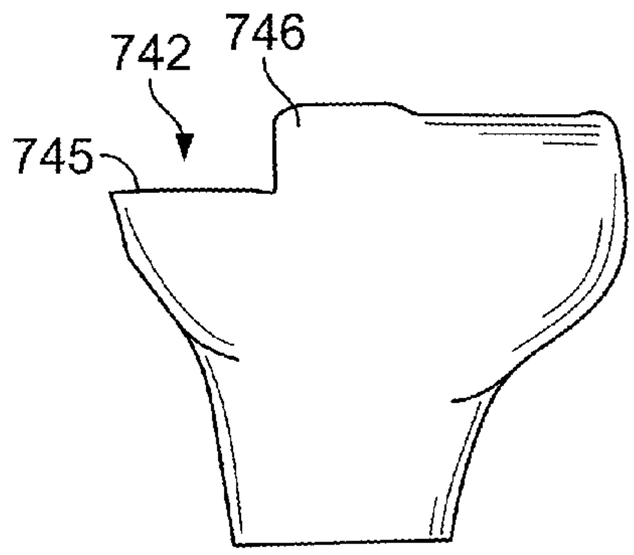

FIG. 19B

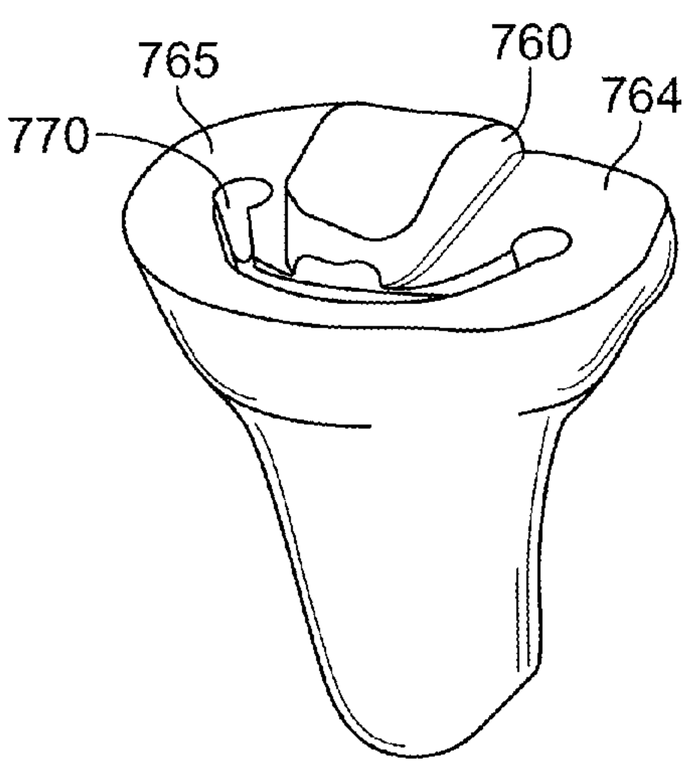

FIG. 20A

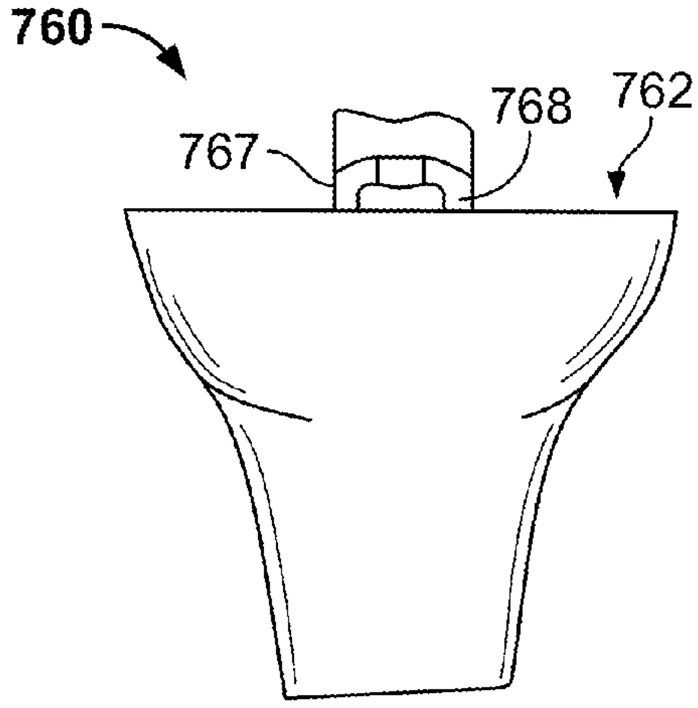

FIG. 20B

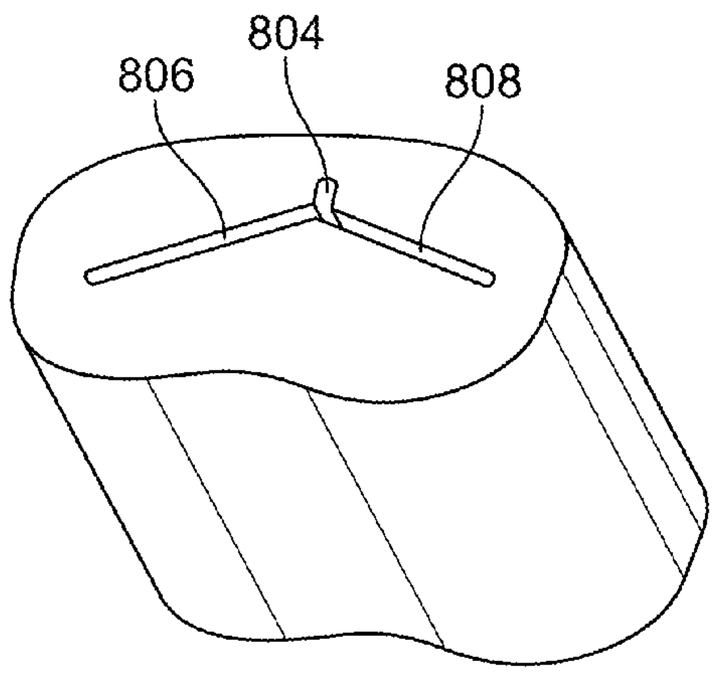

FIG. 21A

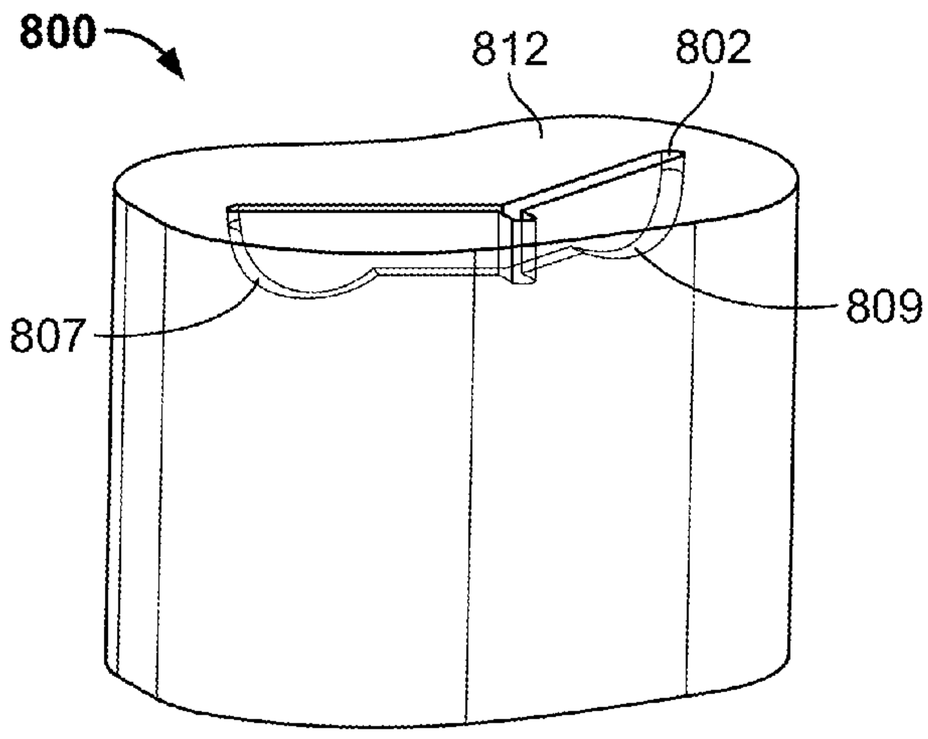

FIG. 21B

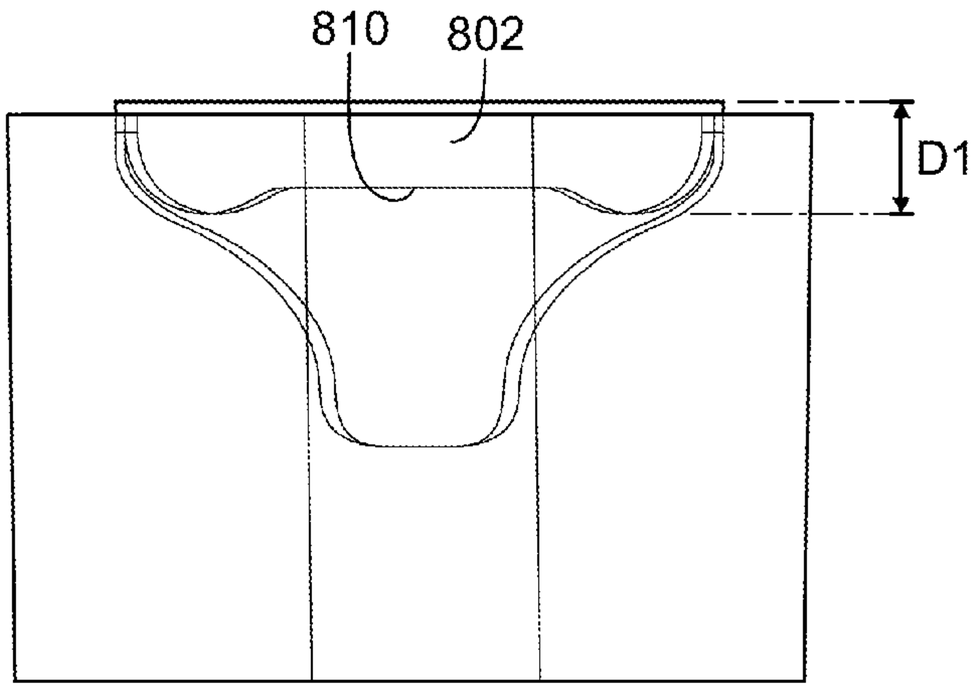

FIG. 21C

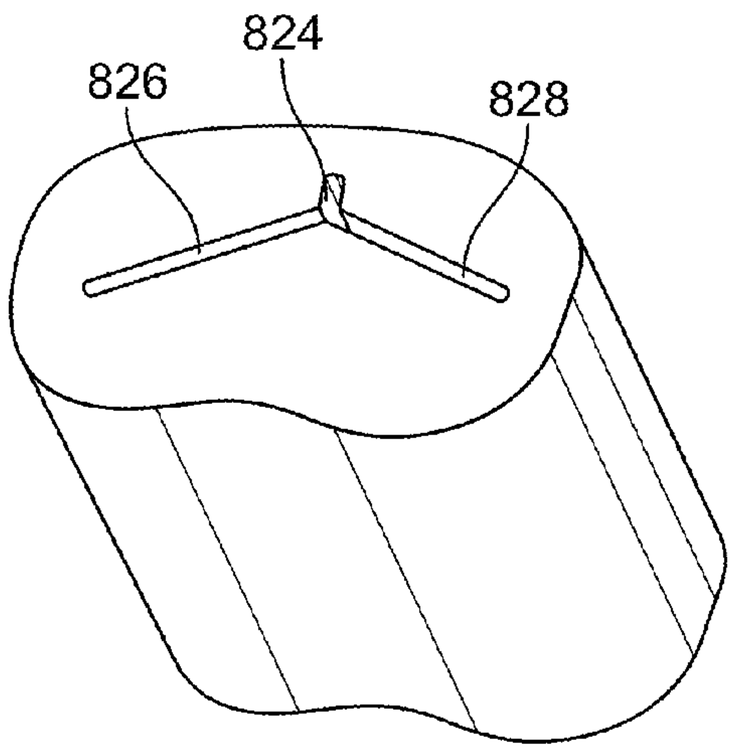

FIG. 22A

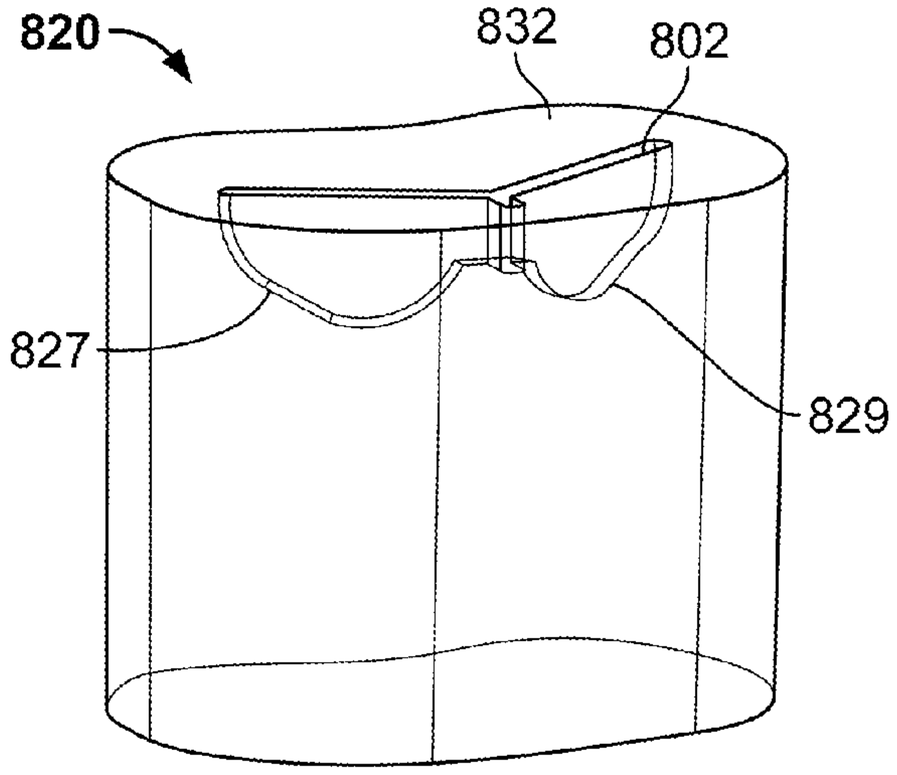

FIG. 22B

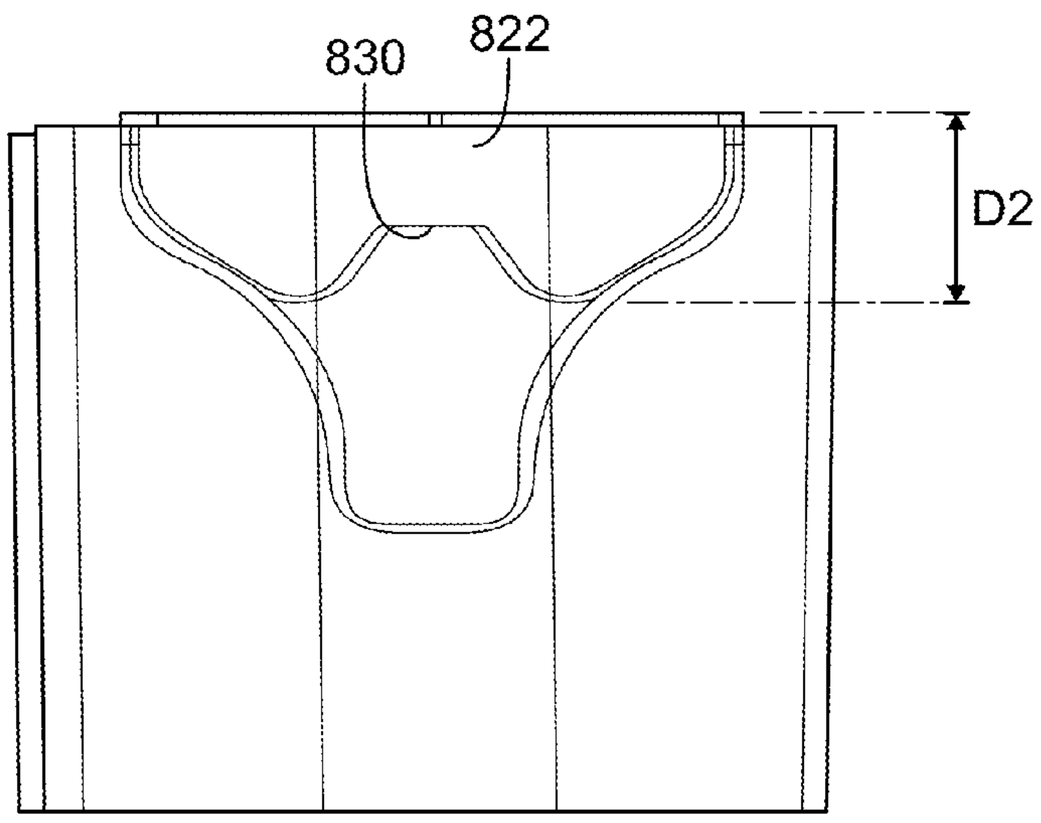

FIG. 22C

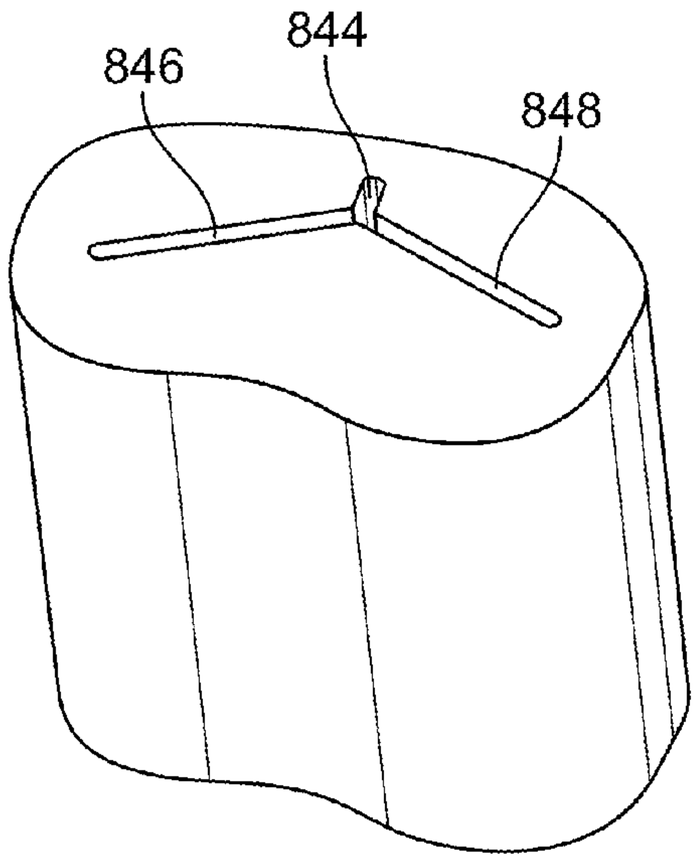

FIG. 23A

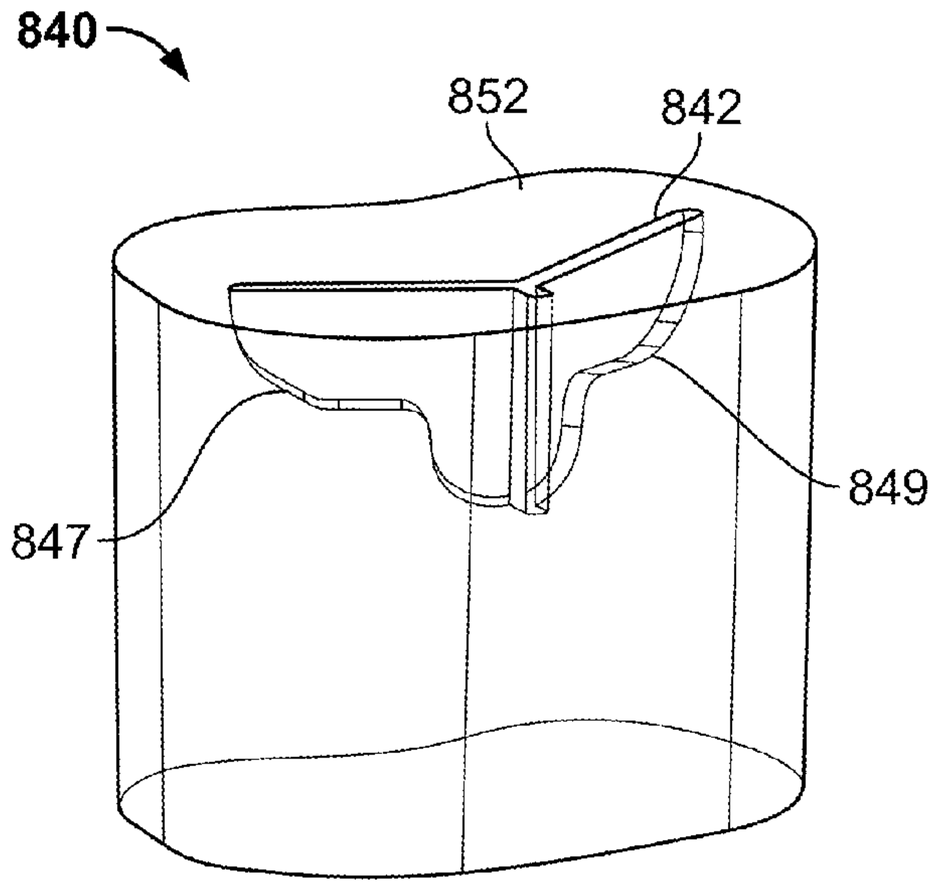

FIG. 23B

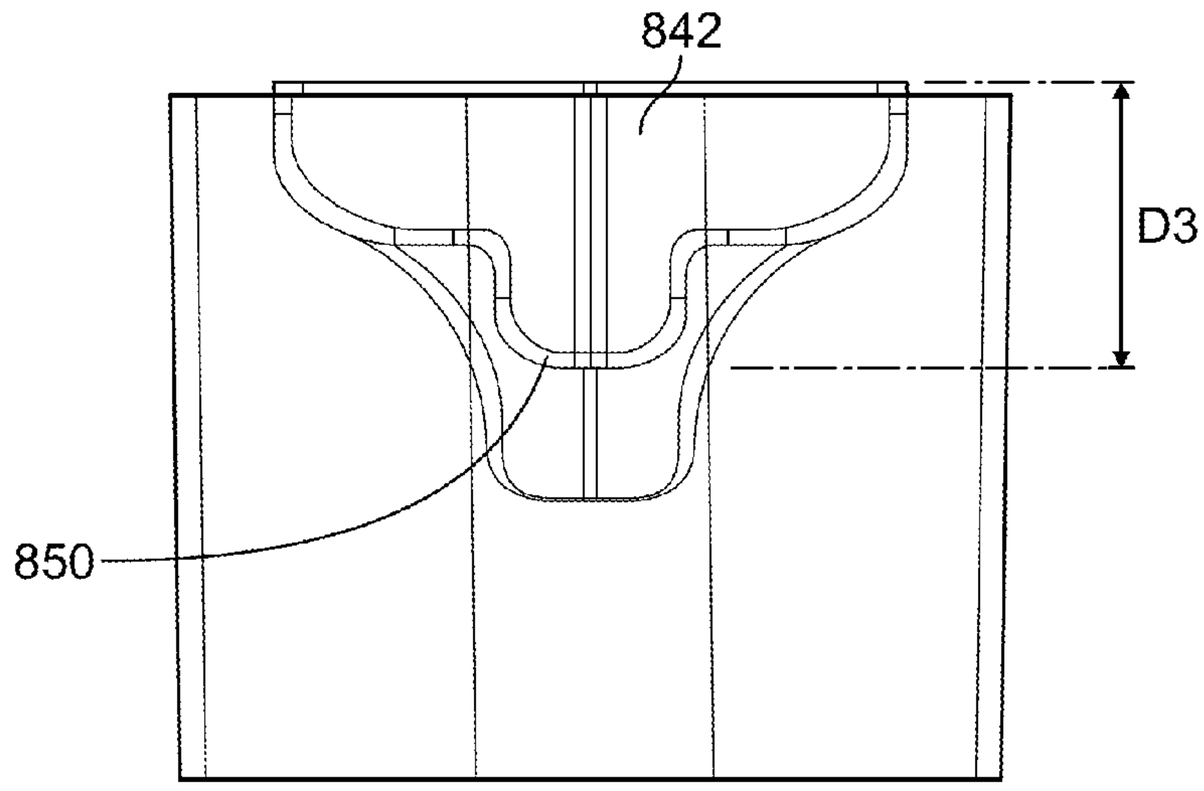

FIG. 23C

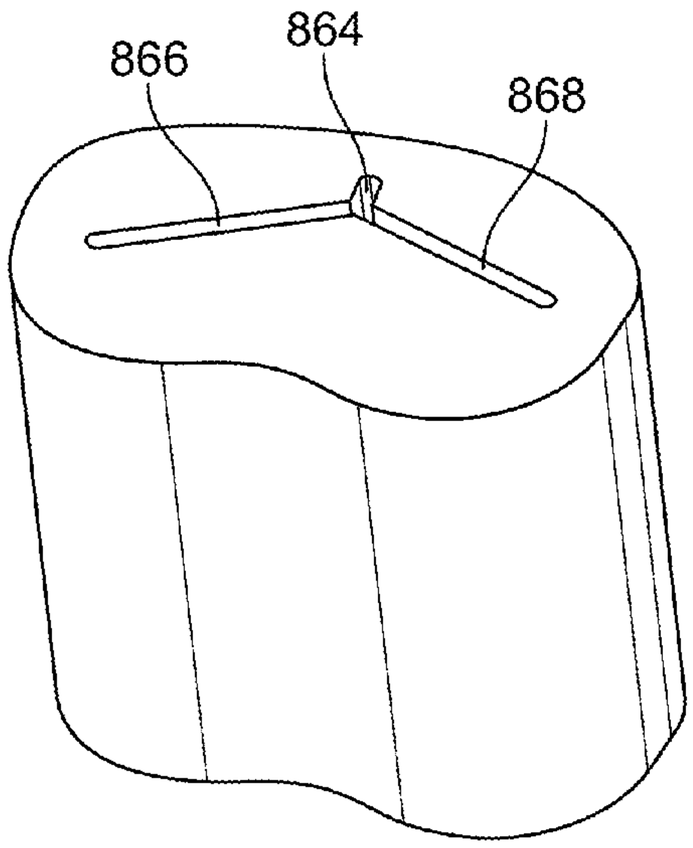

FIG. 24A

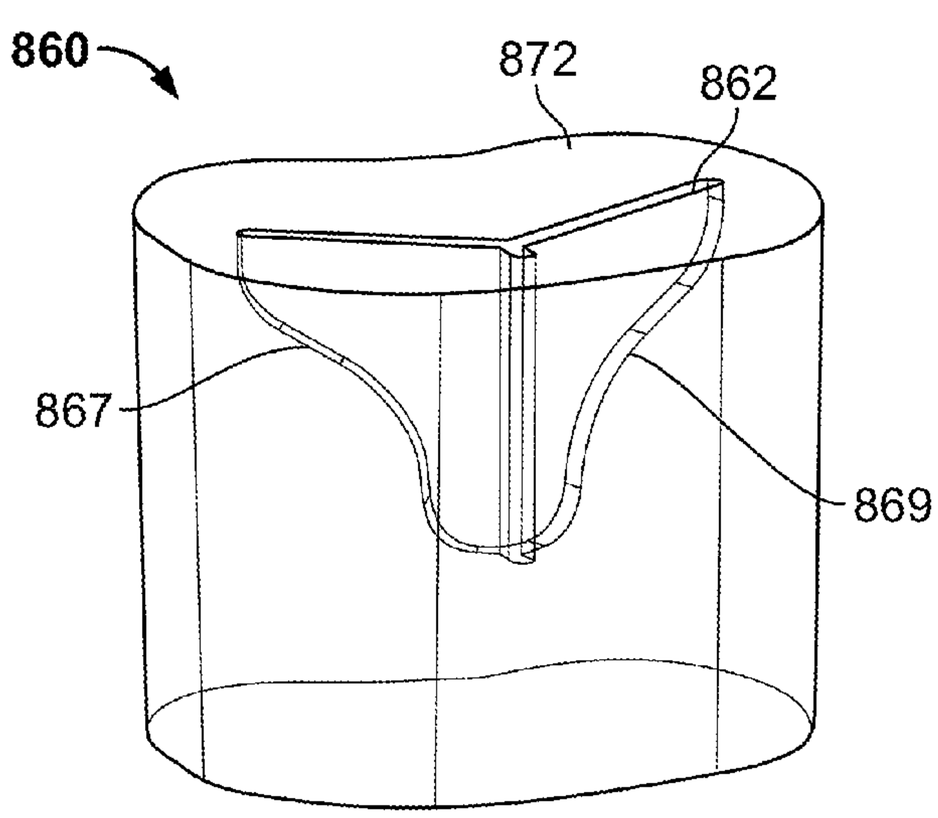

FIG. 24B

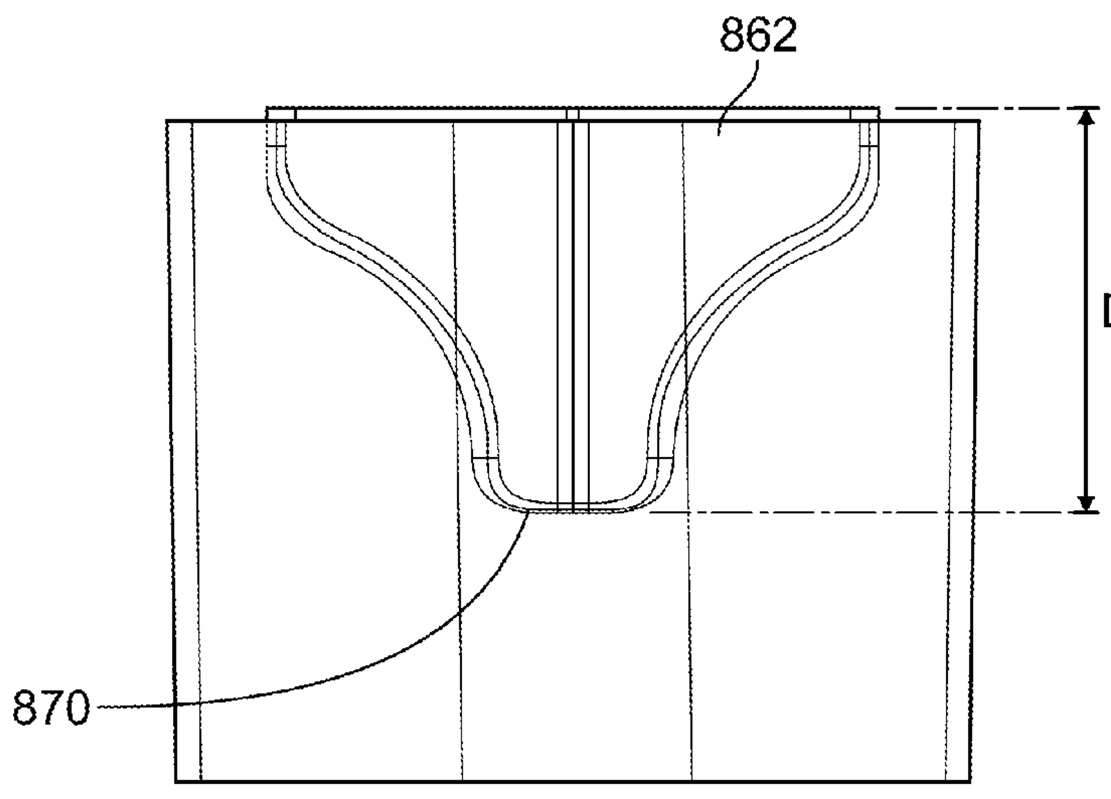

FIG. 24C

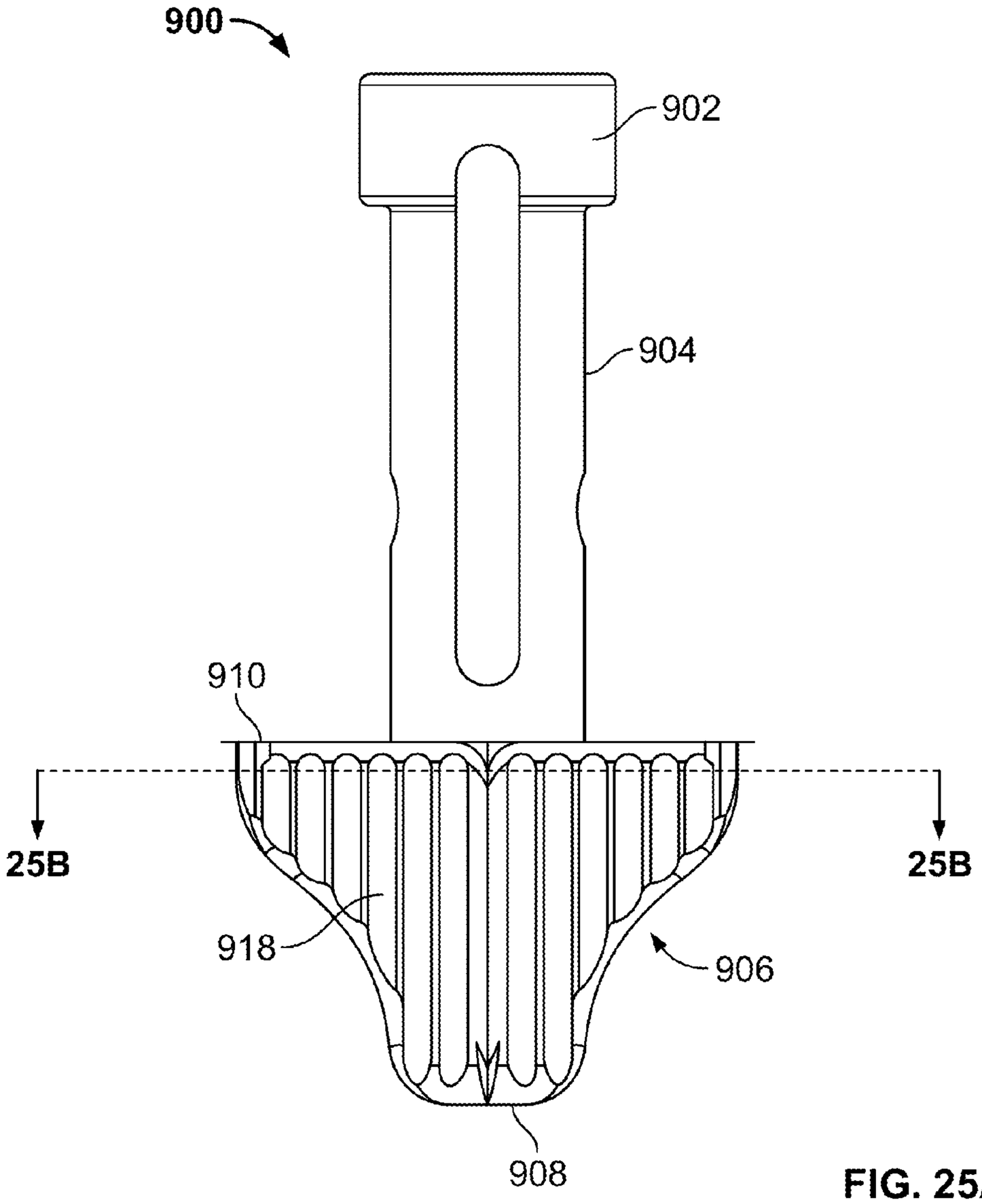

FIG. 25A

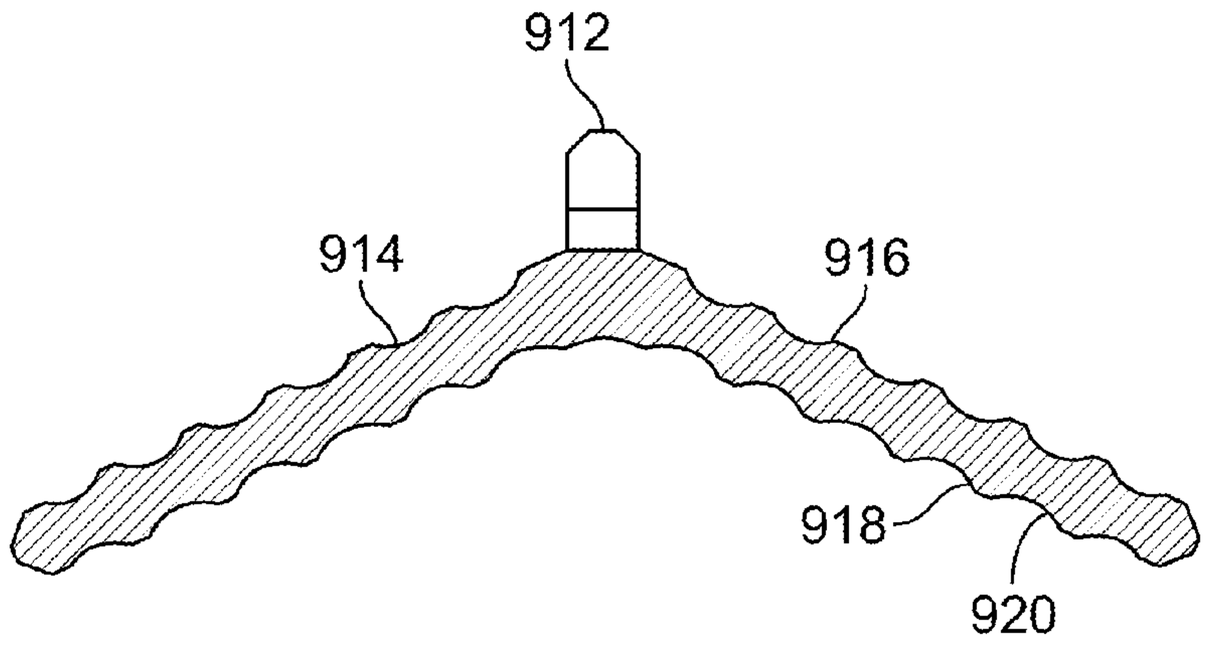

FIG. 25B

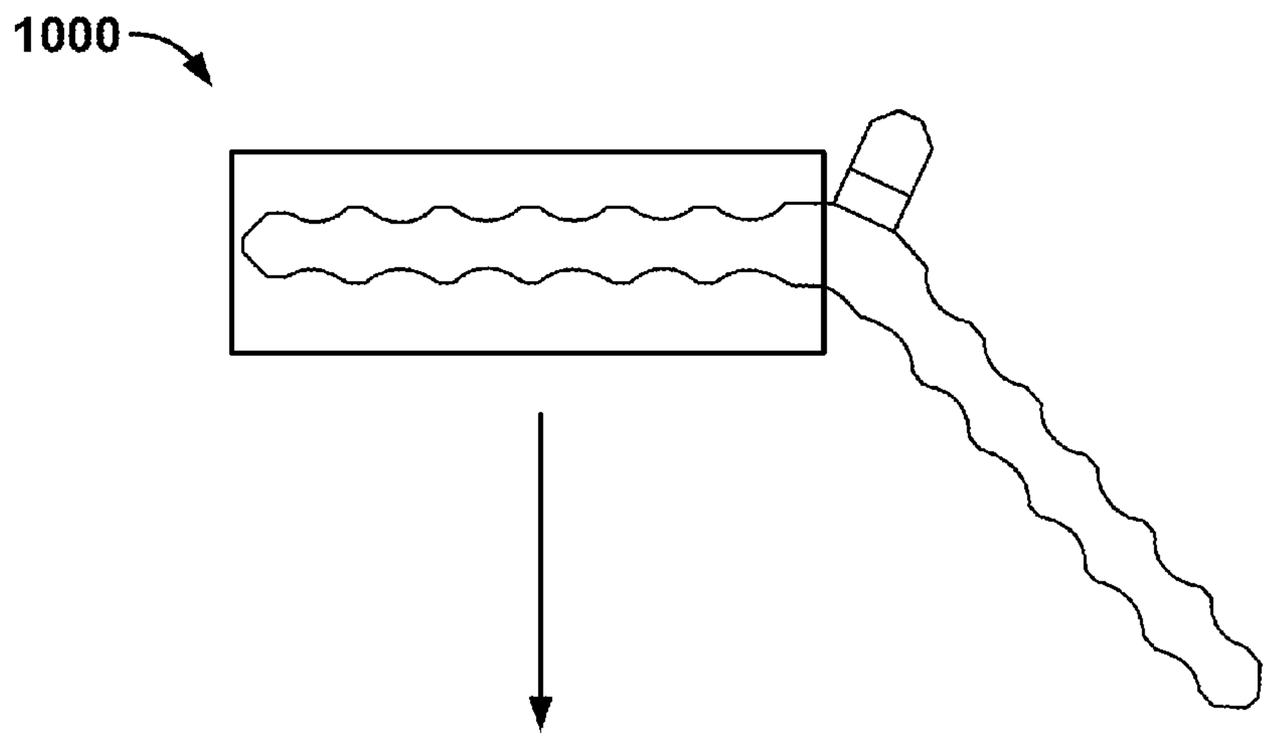

FIG. 26A

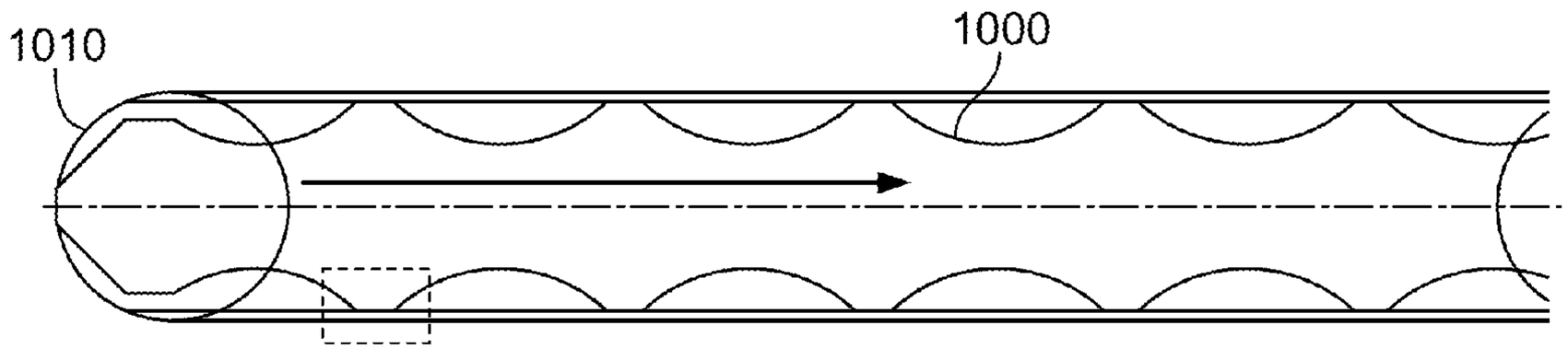

FIG. 26B

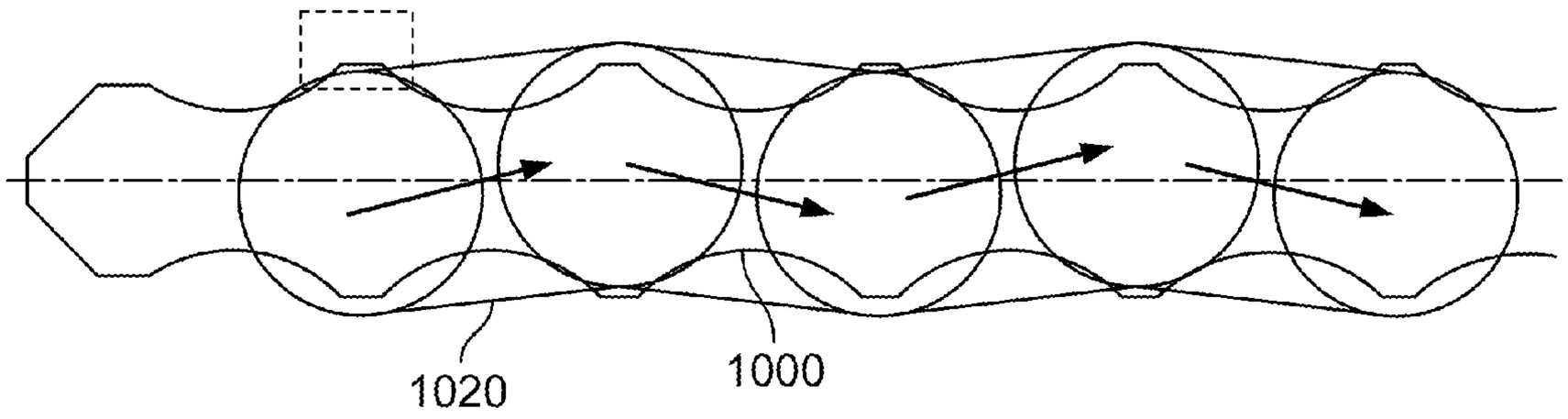

FIG. 26C

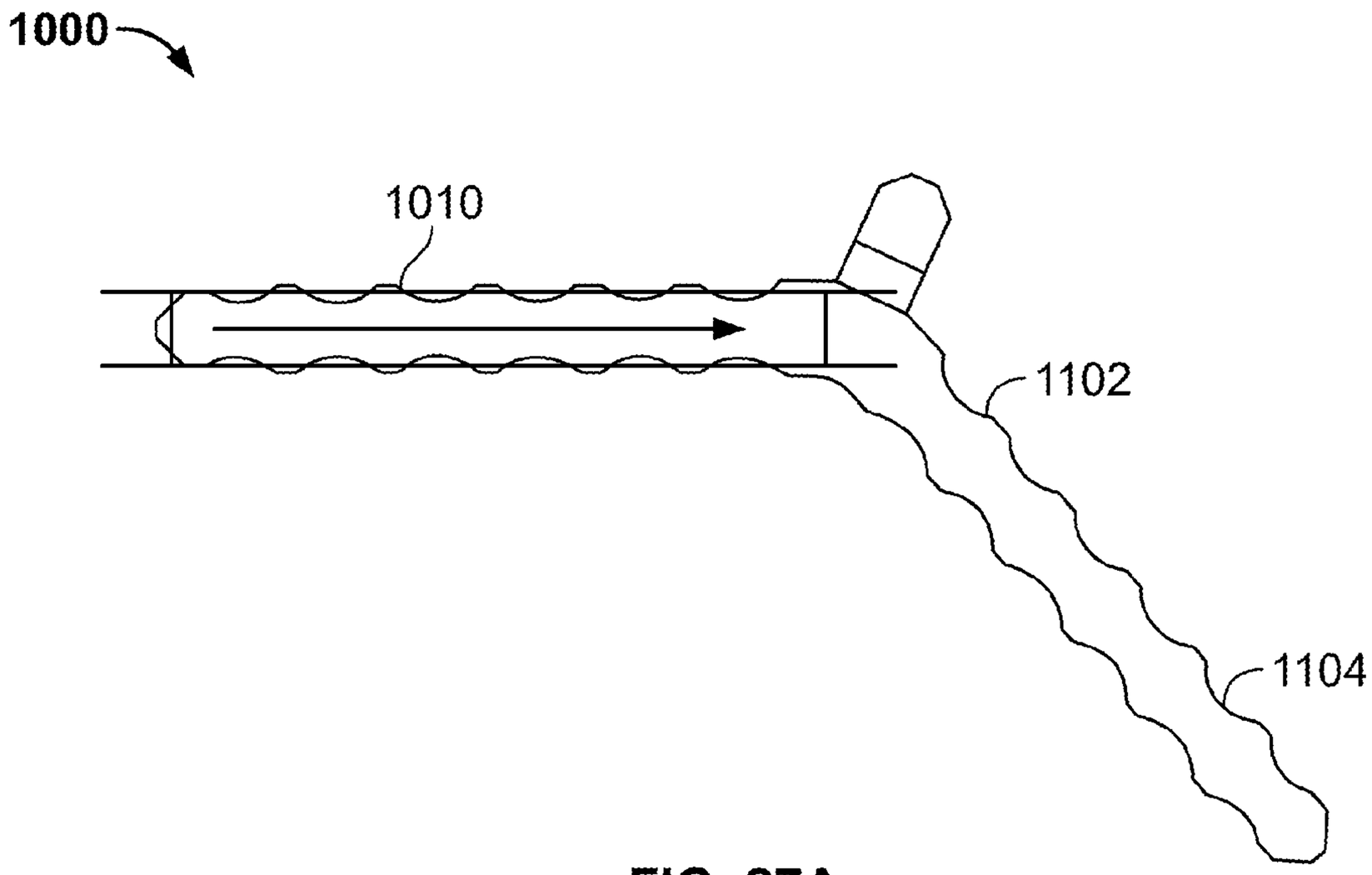

FIG. 27A

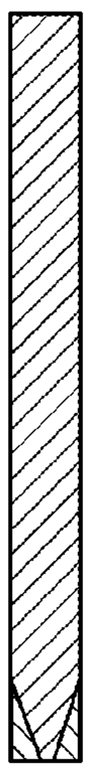

FIG. 27B

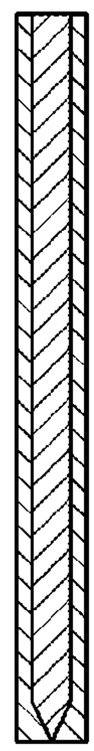

FIG. 27C

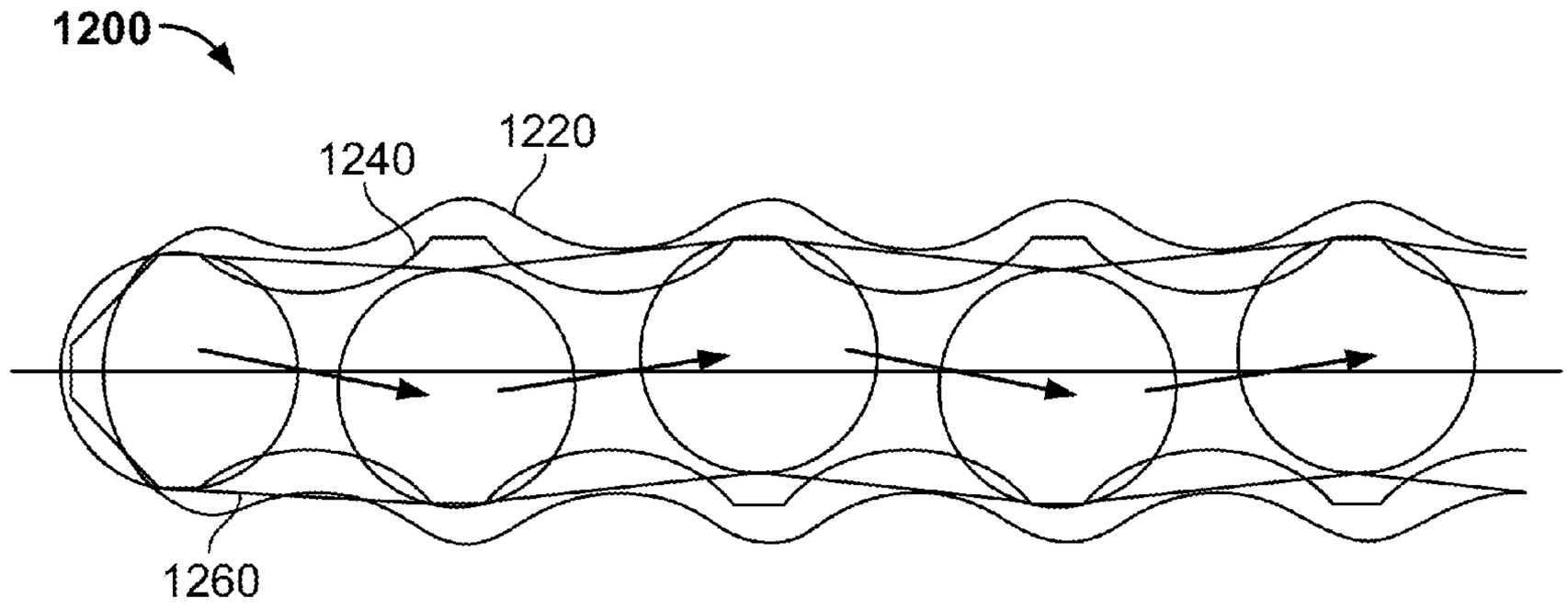

FIG. 28A

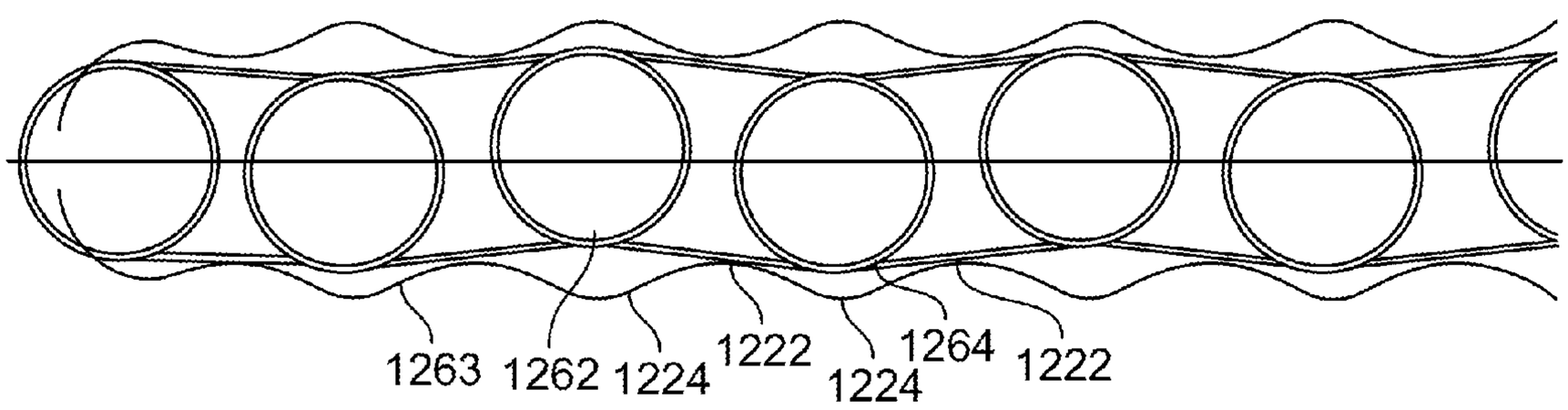

FIG. 28B

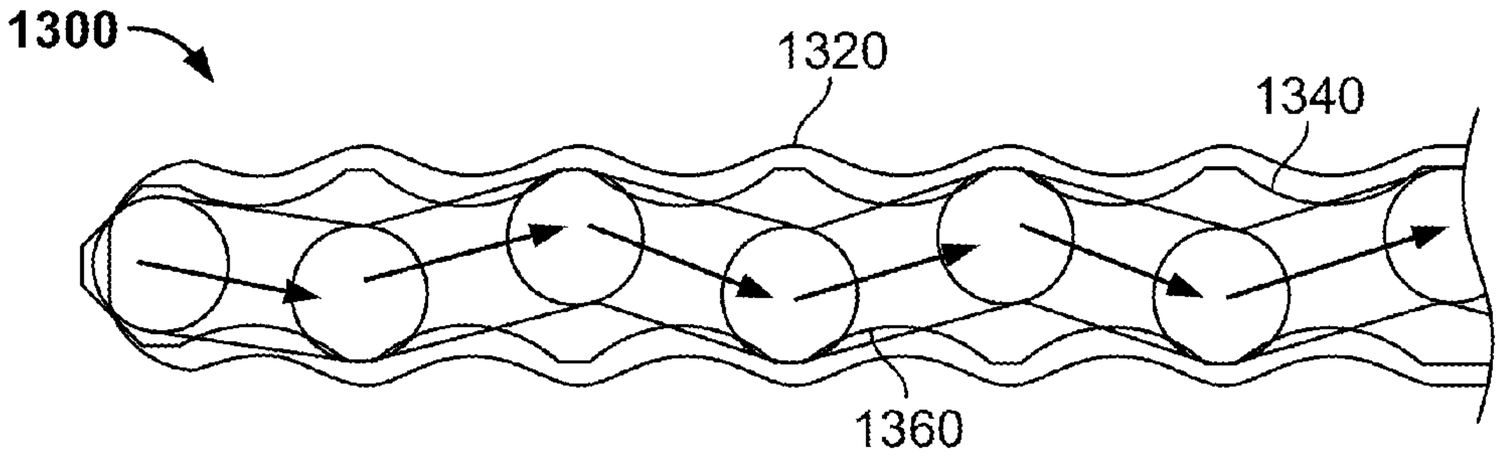

FIG. 29A

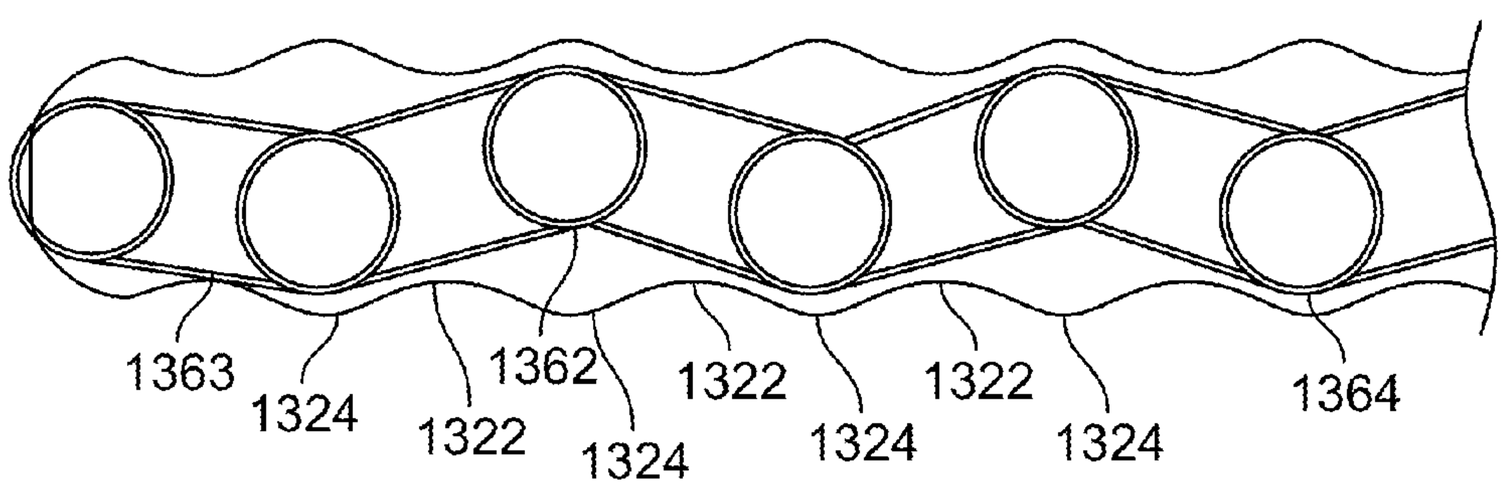

FIG. 29B

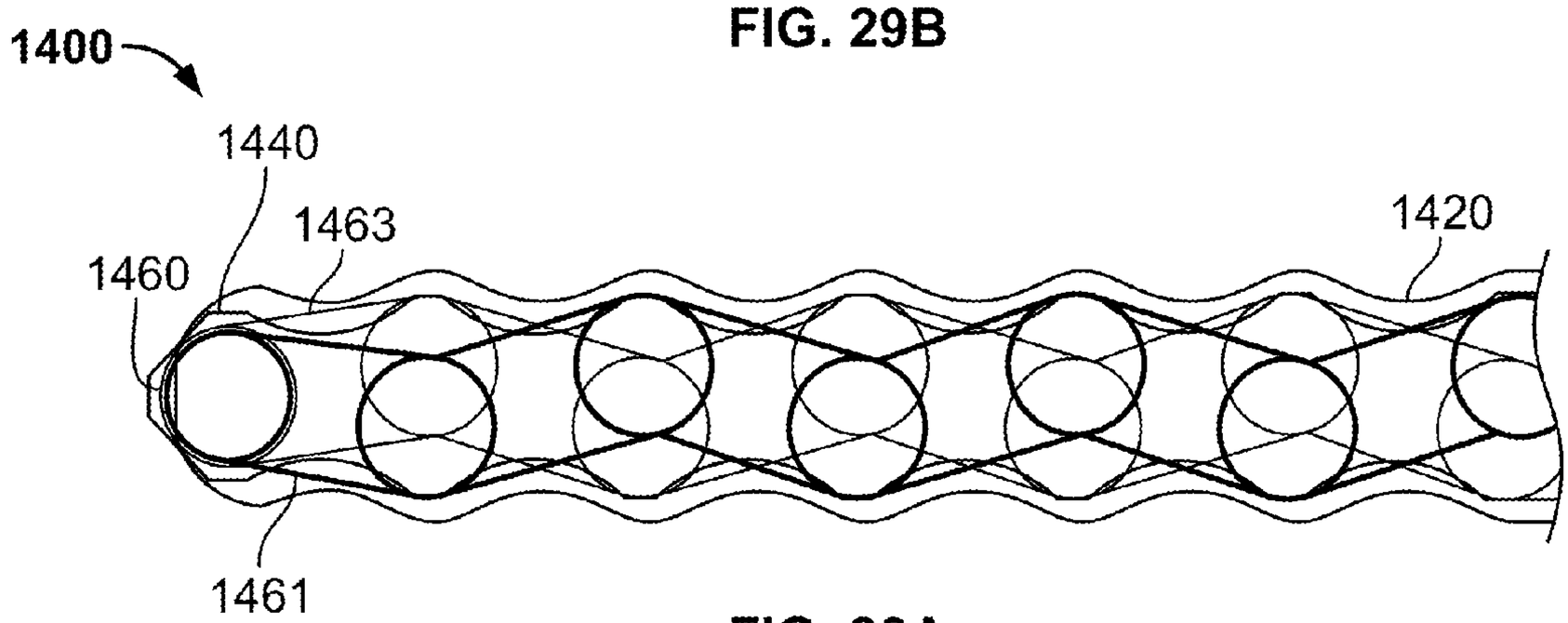

FIG. 30A

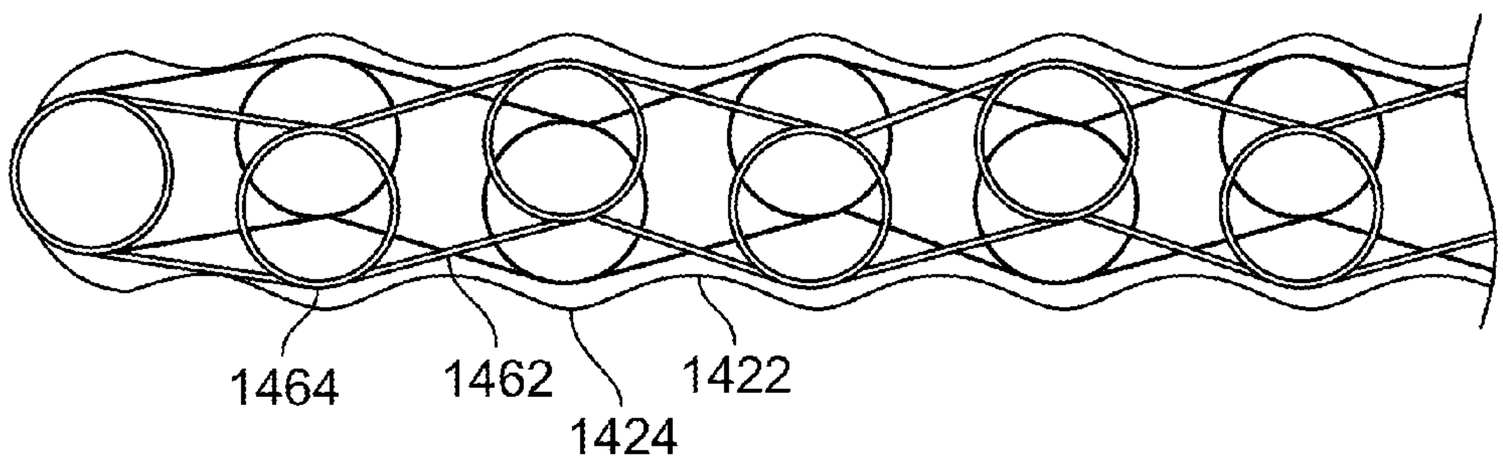

FIG. 30B

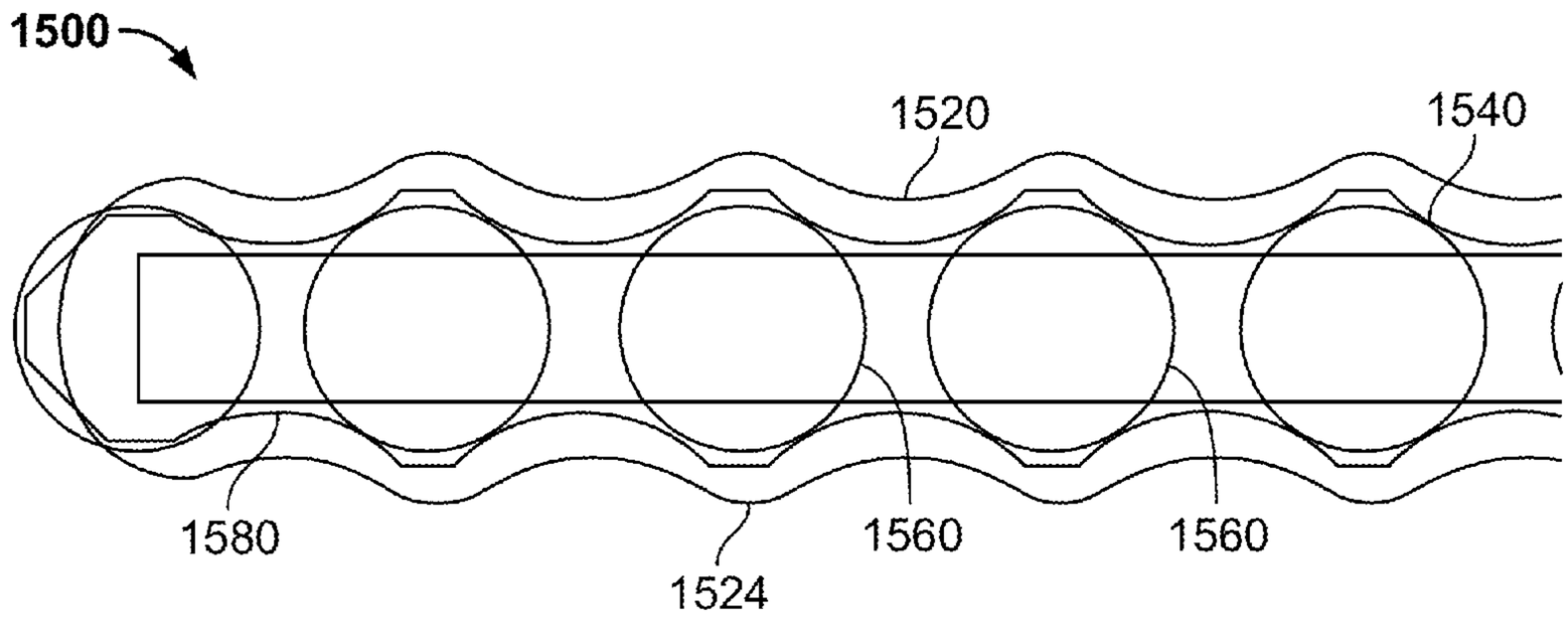

FIG. 31A

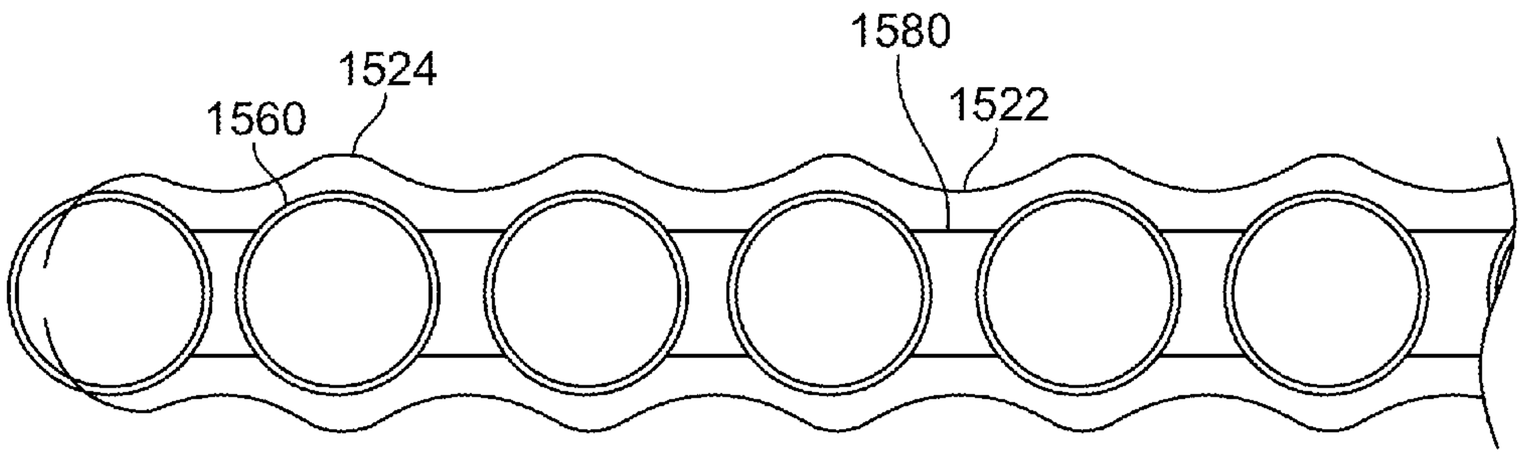

FIG. 31B

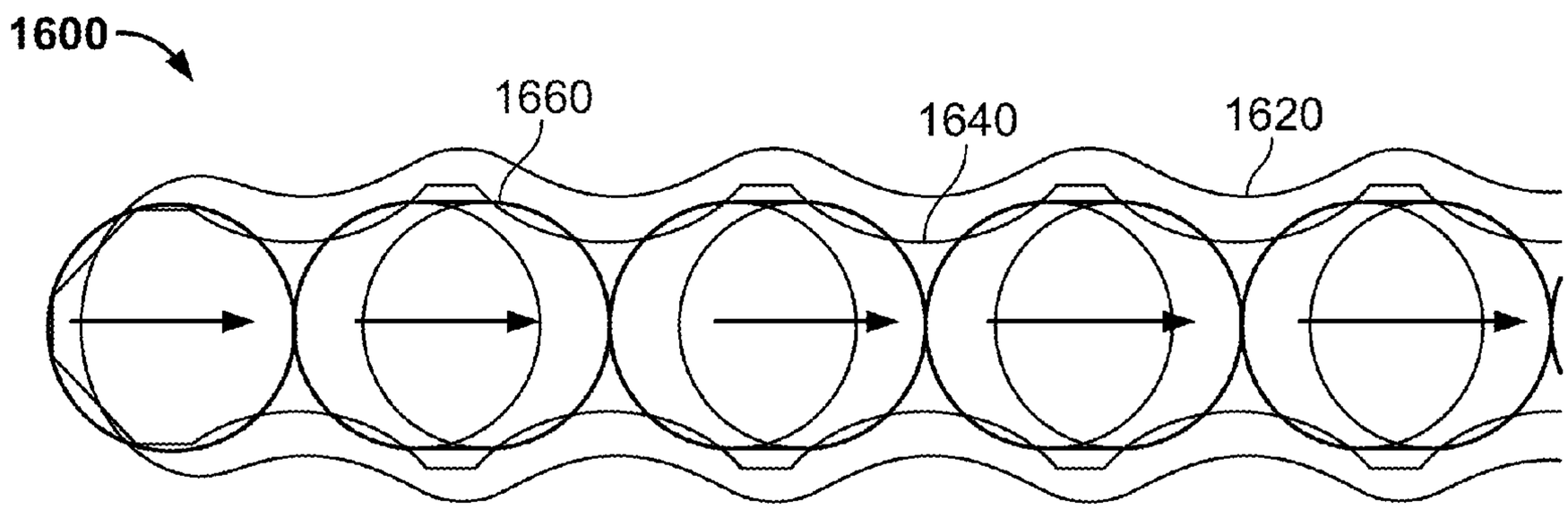

FIG. 32A

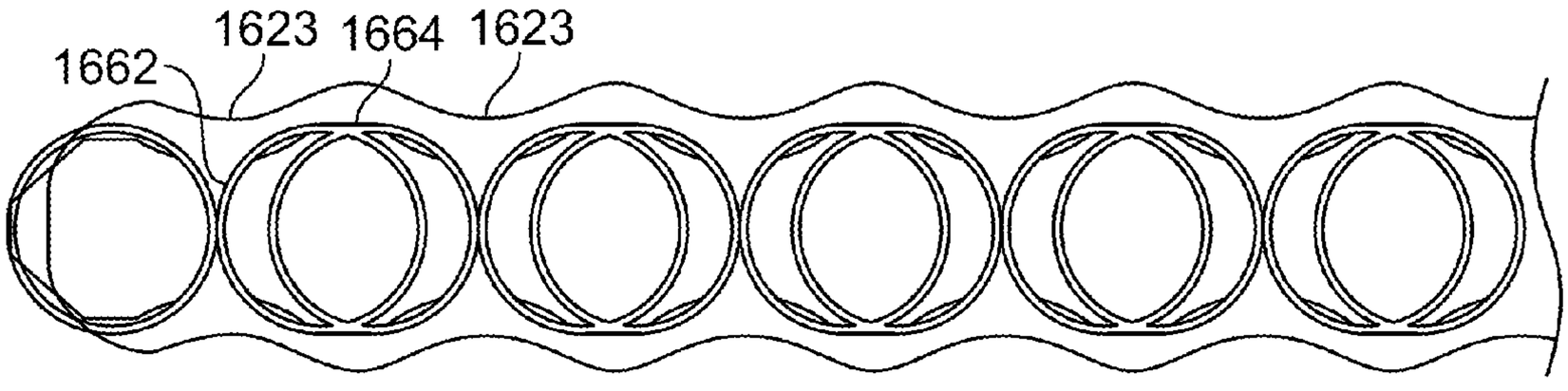

FIG. 32B

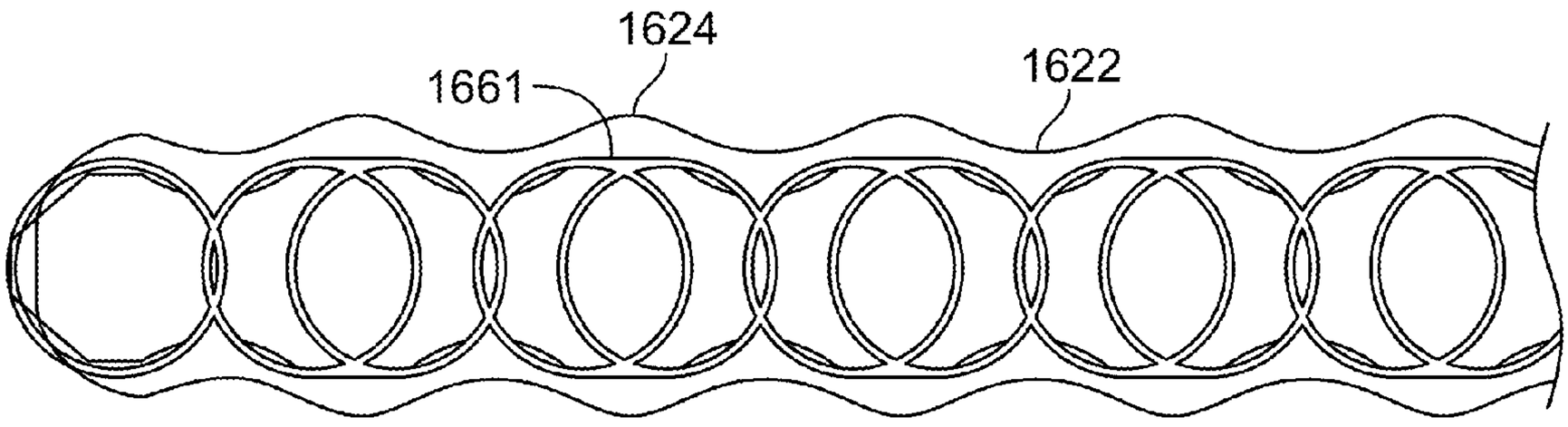

FIG. 32C

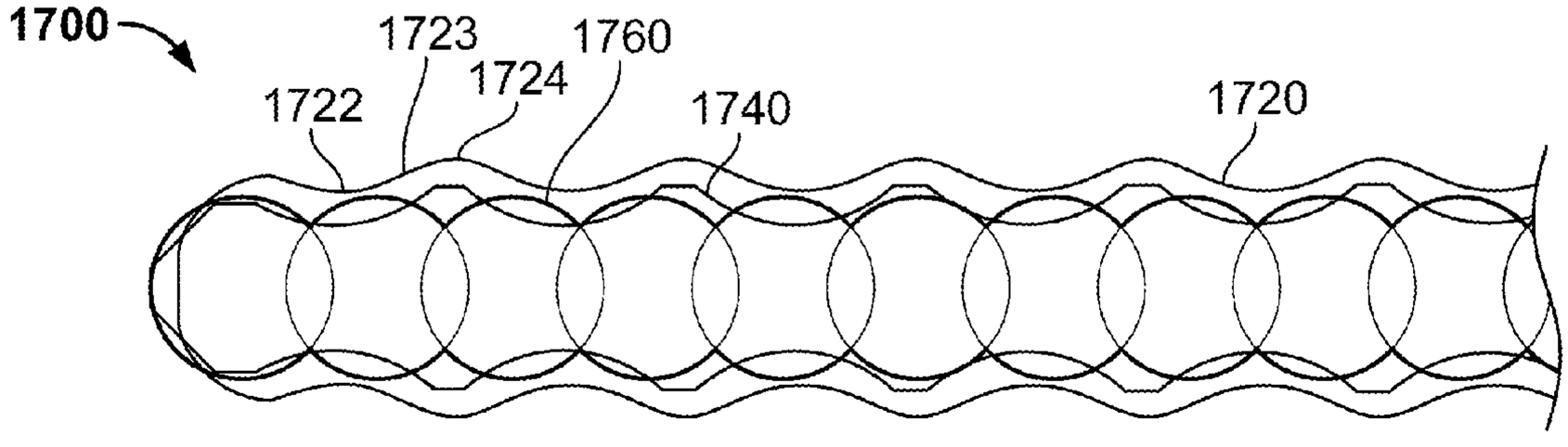

FIG. 33A

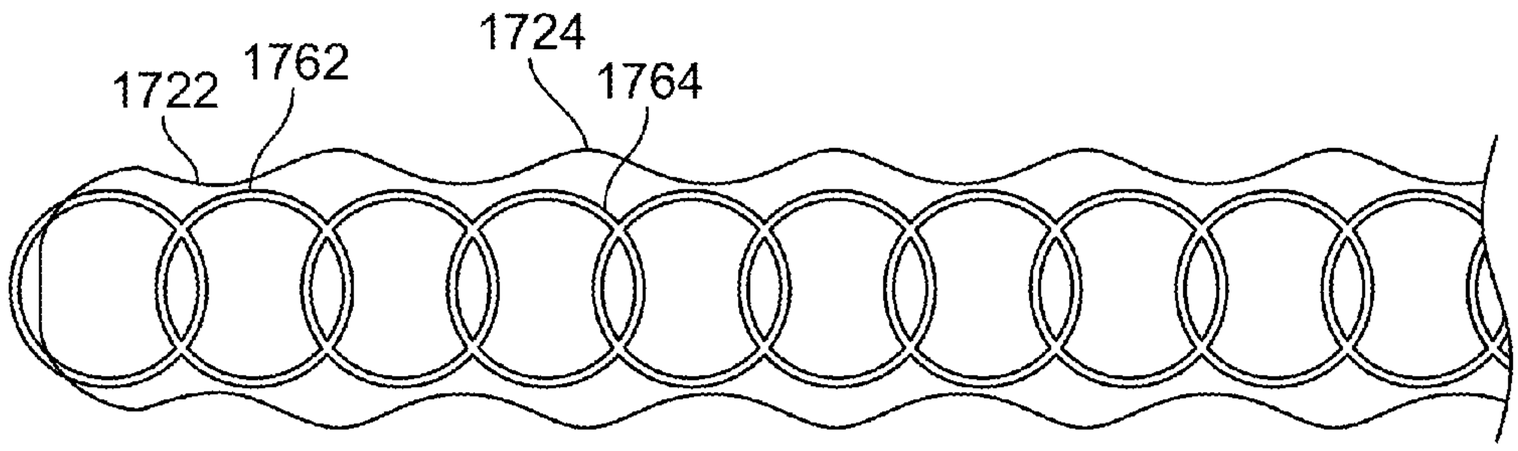

FIG. 33B

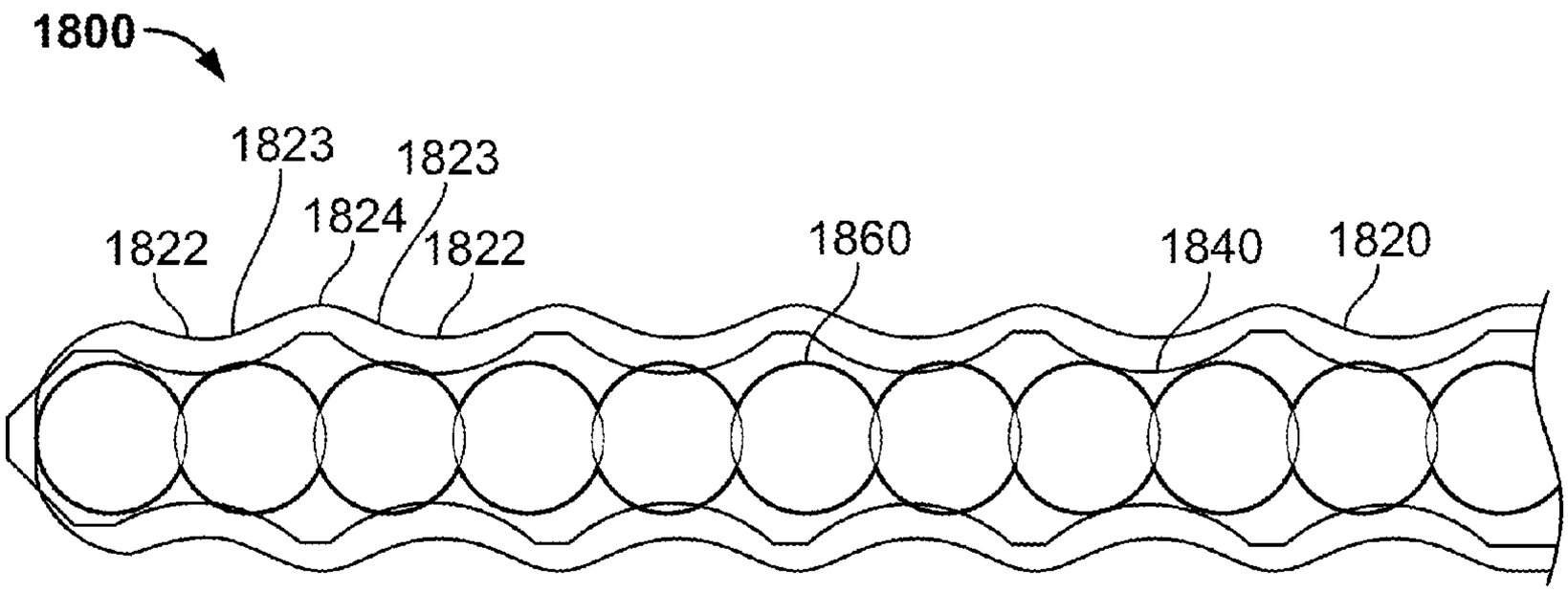

FIG. 34A

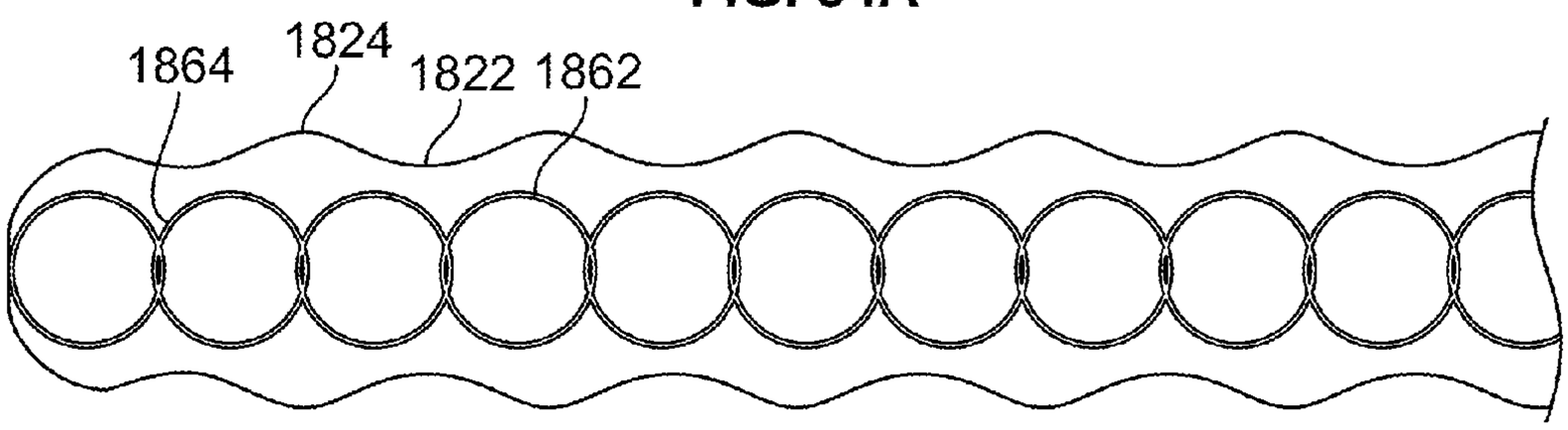

FIG. 34B

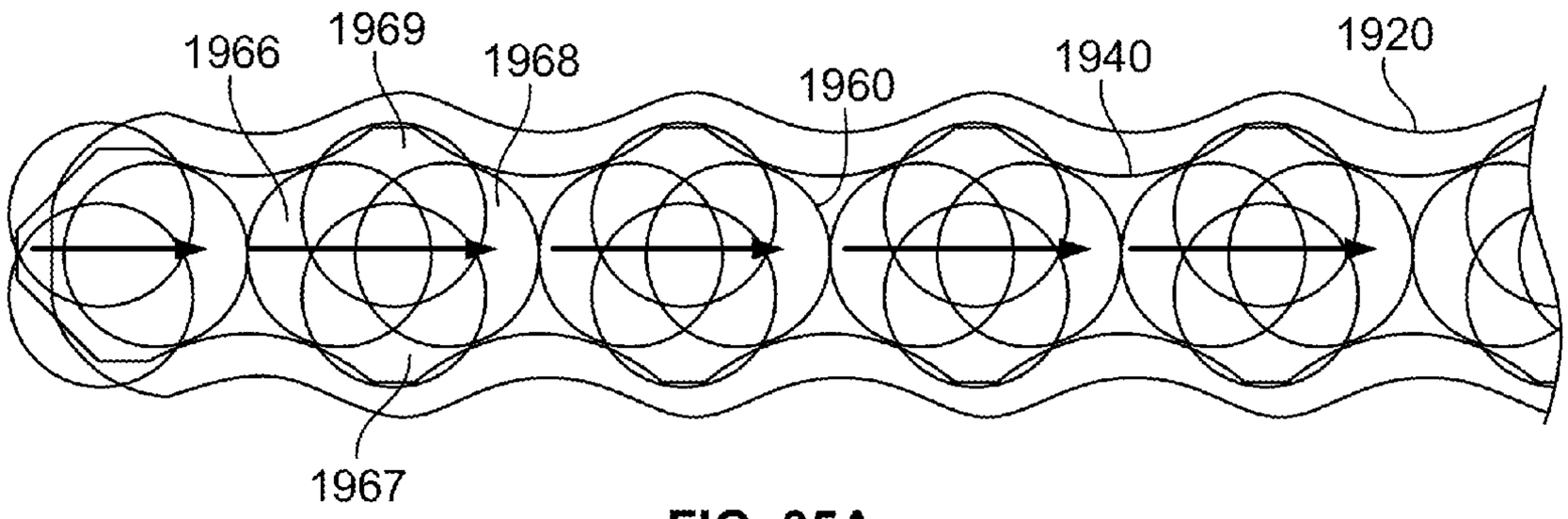

FIG. 35A

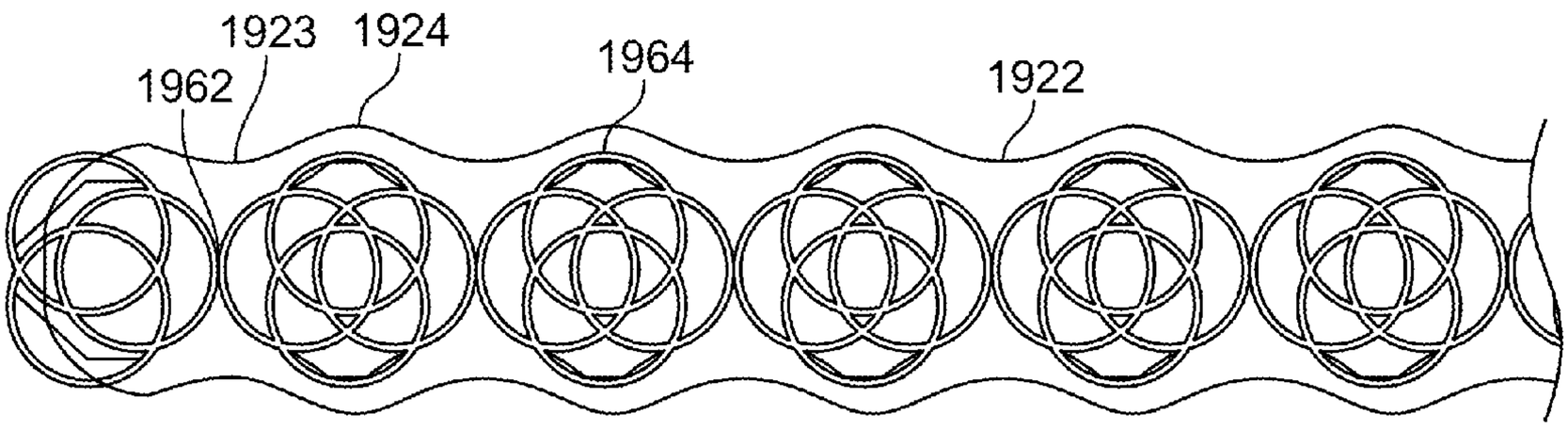

FIG. 35B

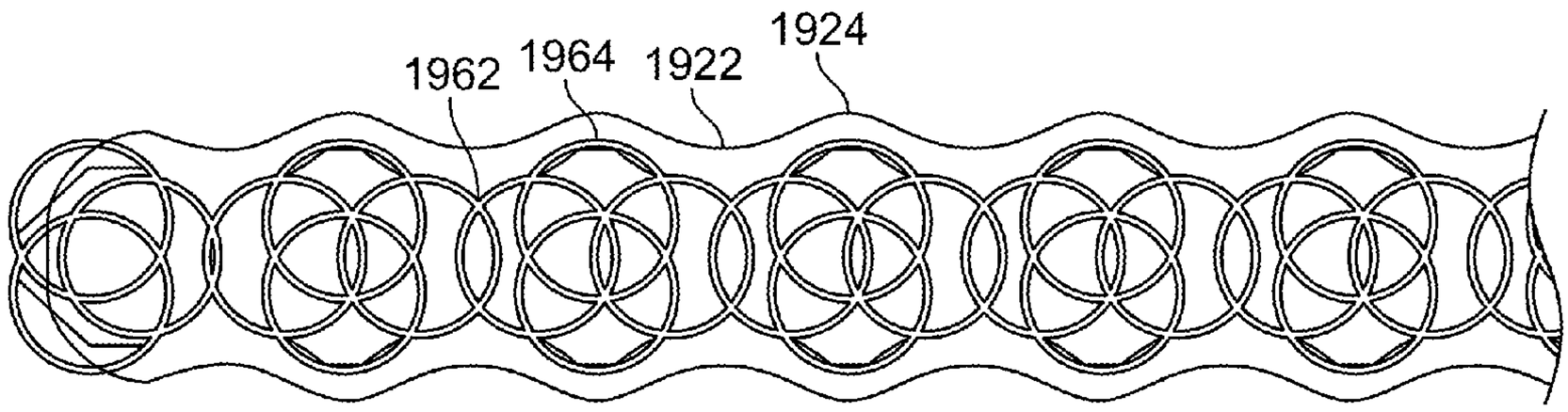

FIG. 35C

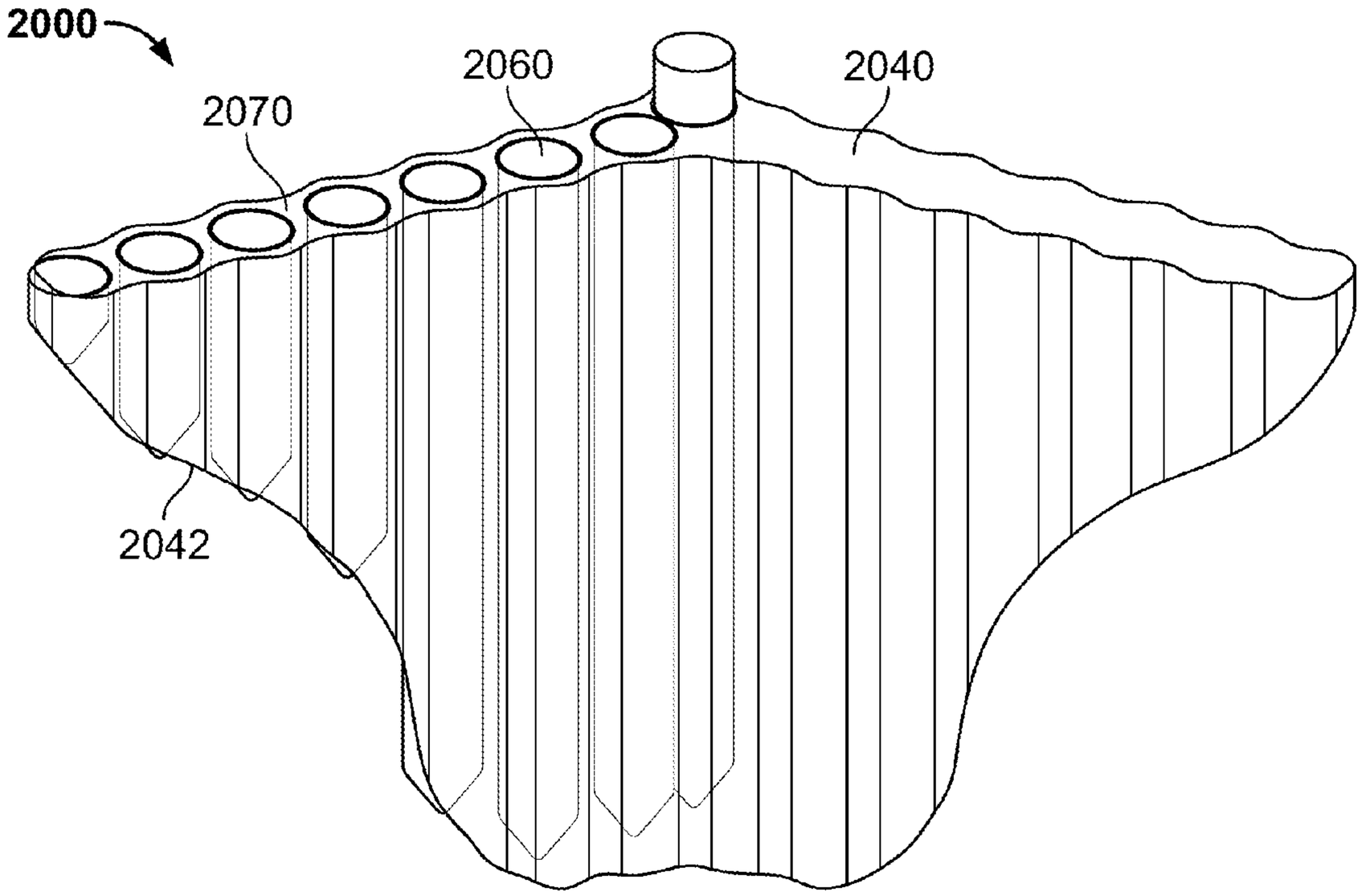

FIG. 36A

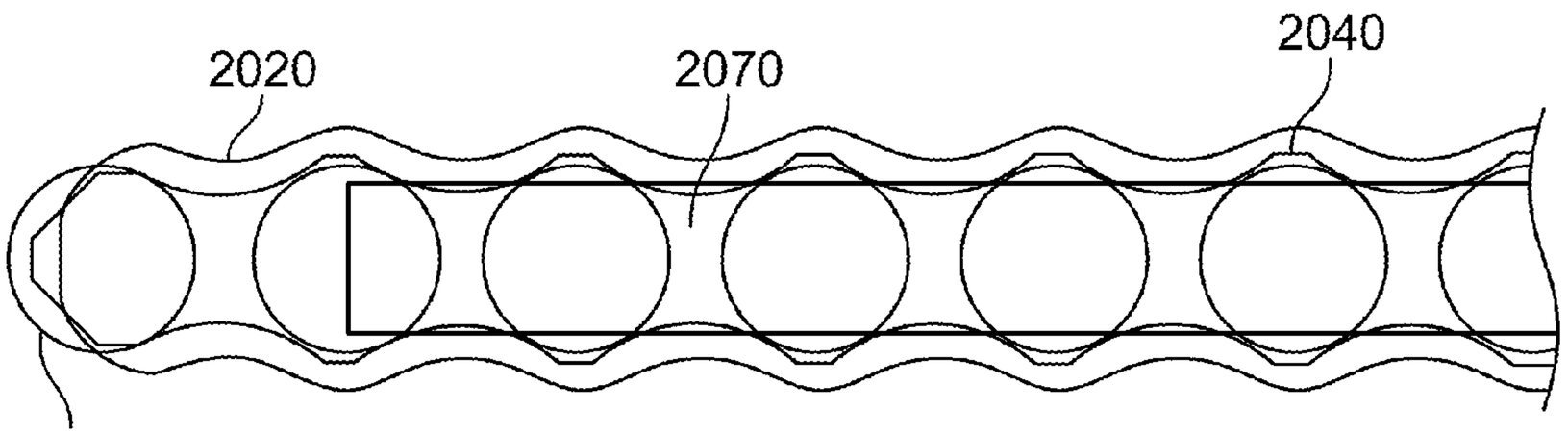

FIG. 36B

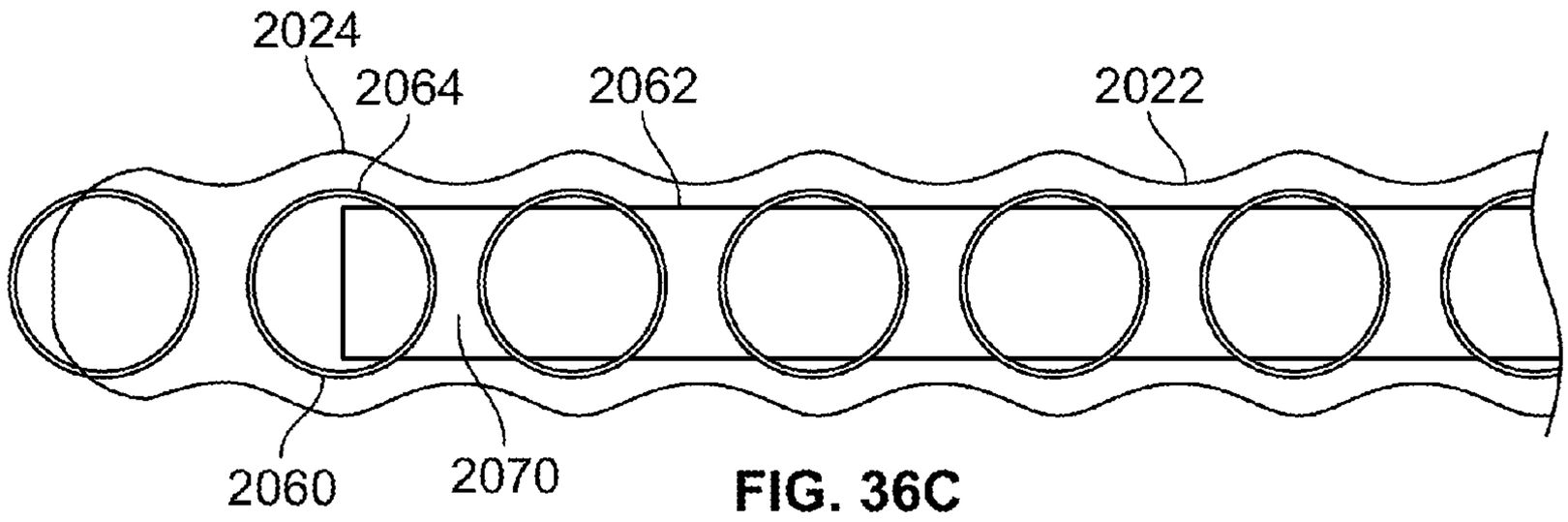

FIG. 36C

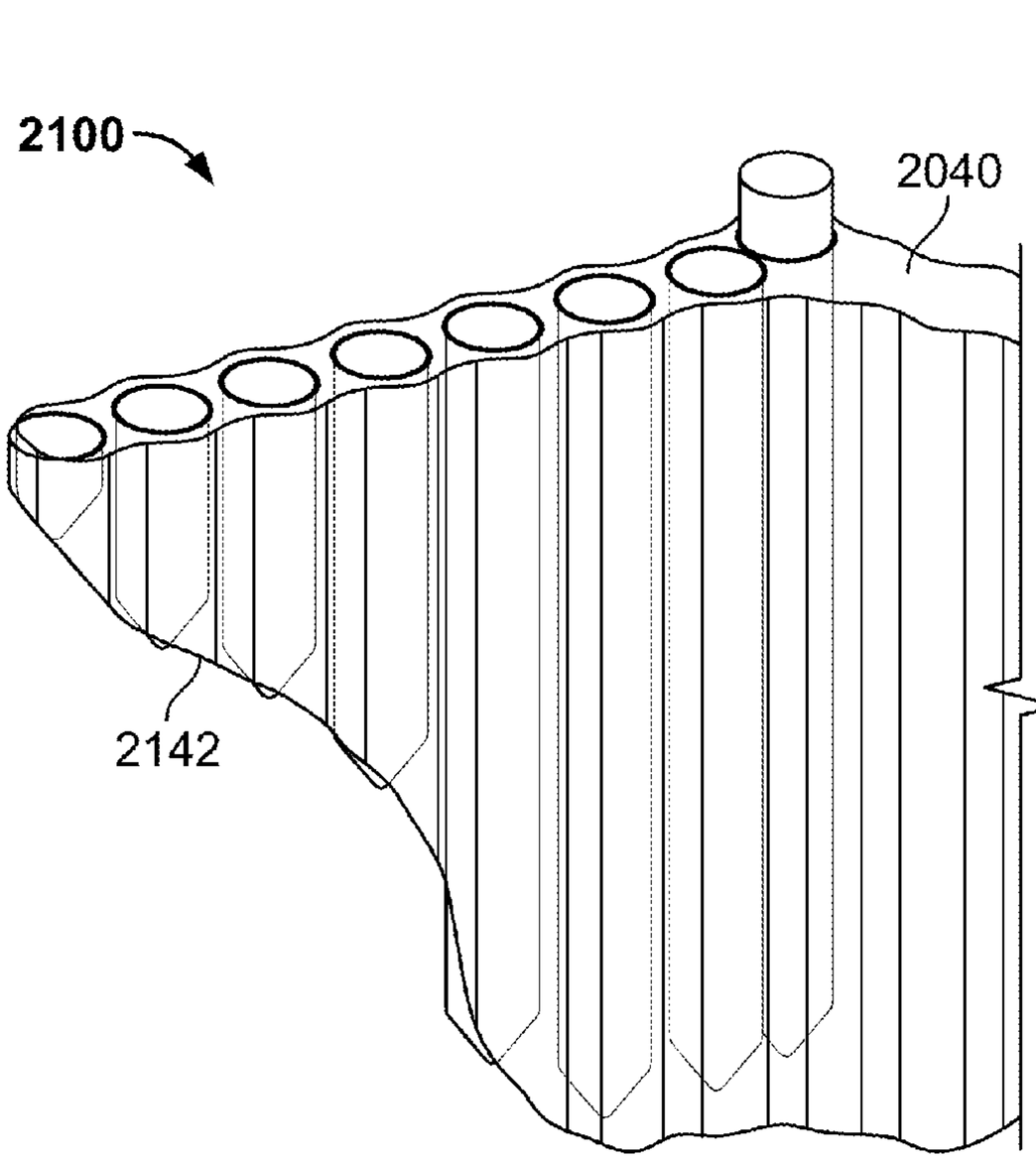

FIG. 37A

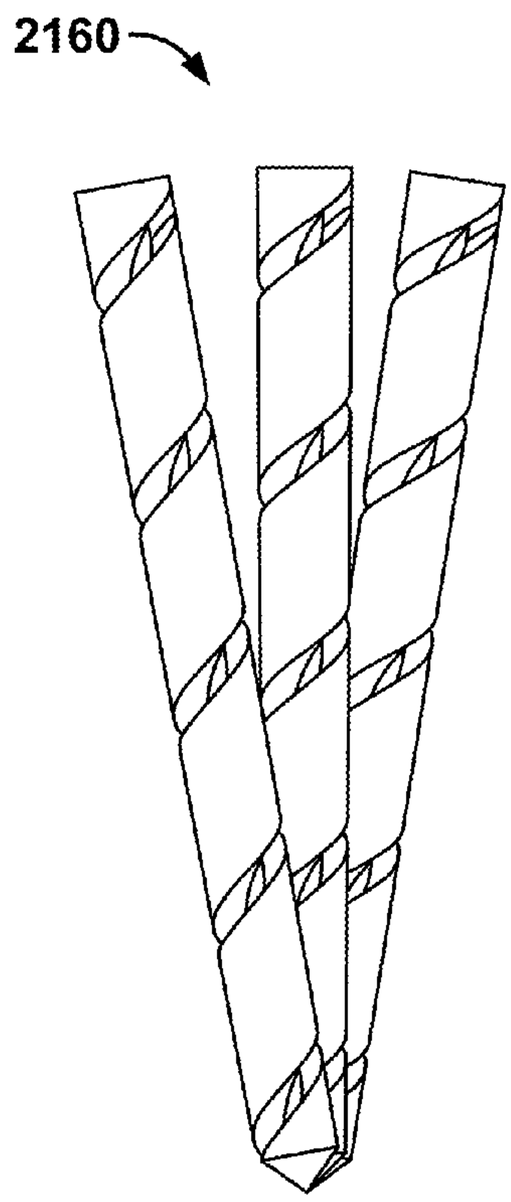

FIG. 37B

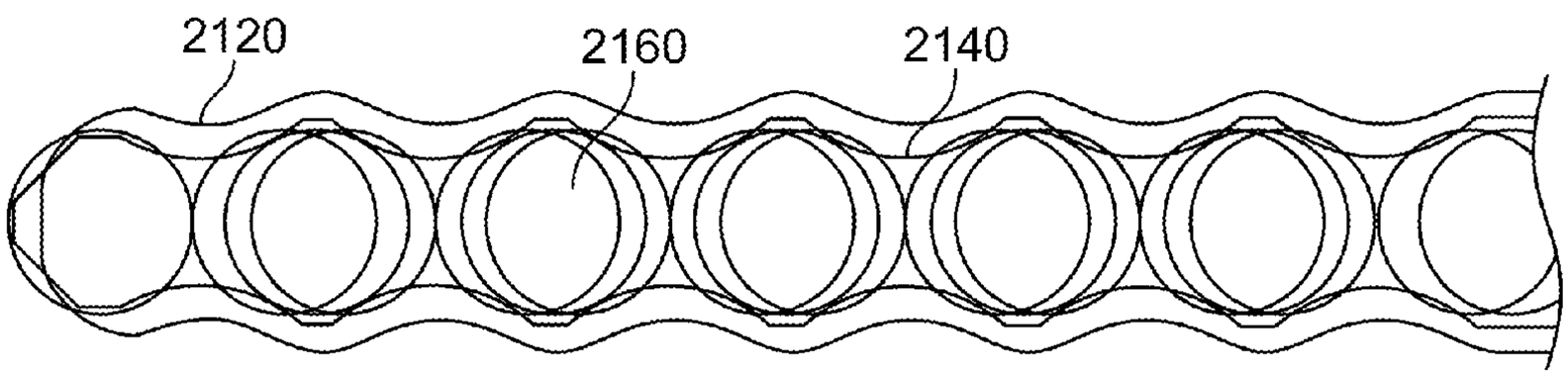

FIG. 37C

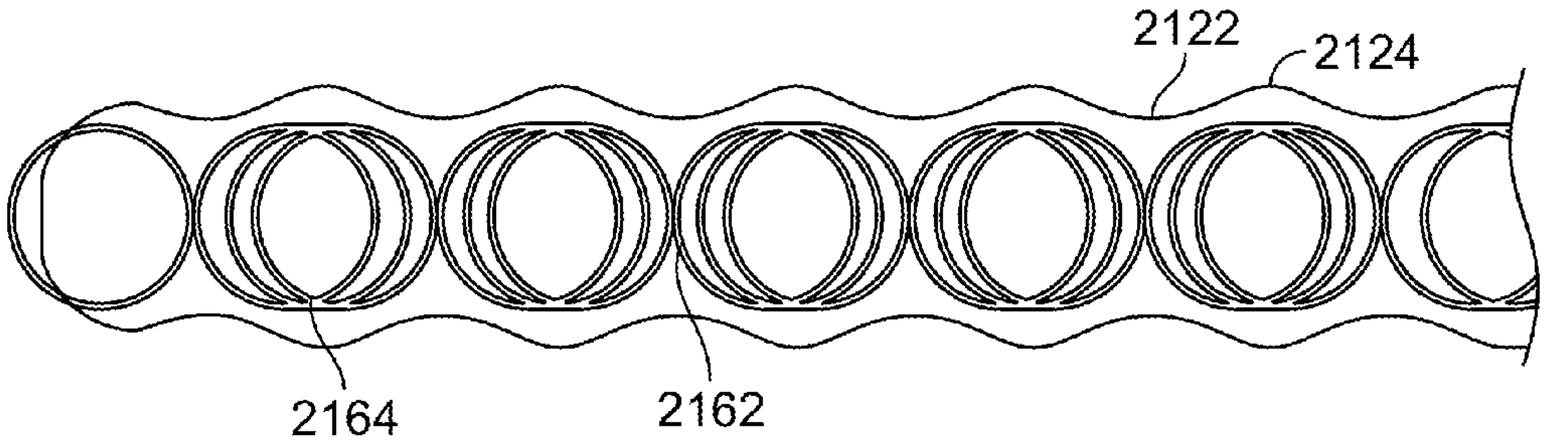

FIG. 37D

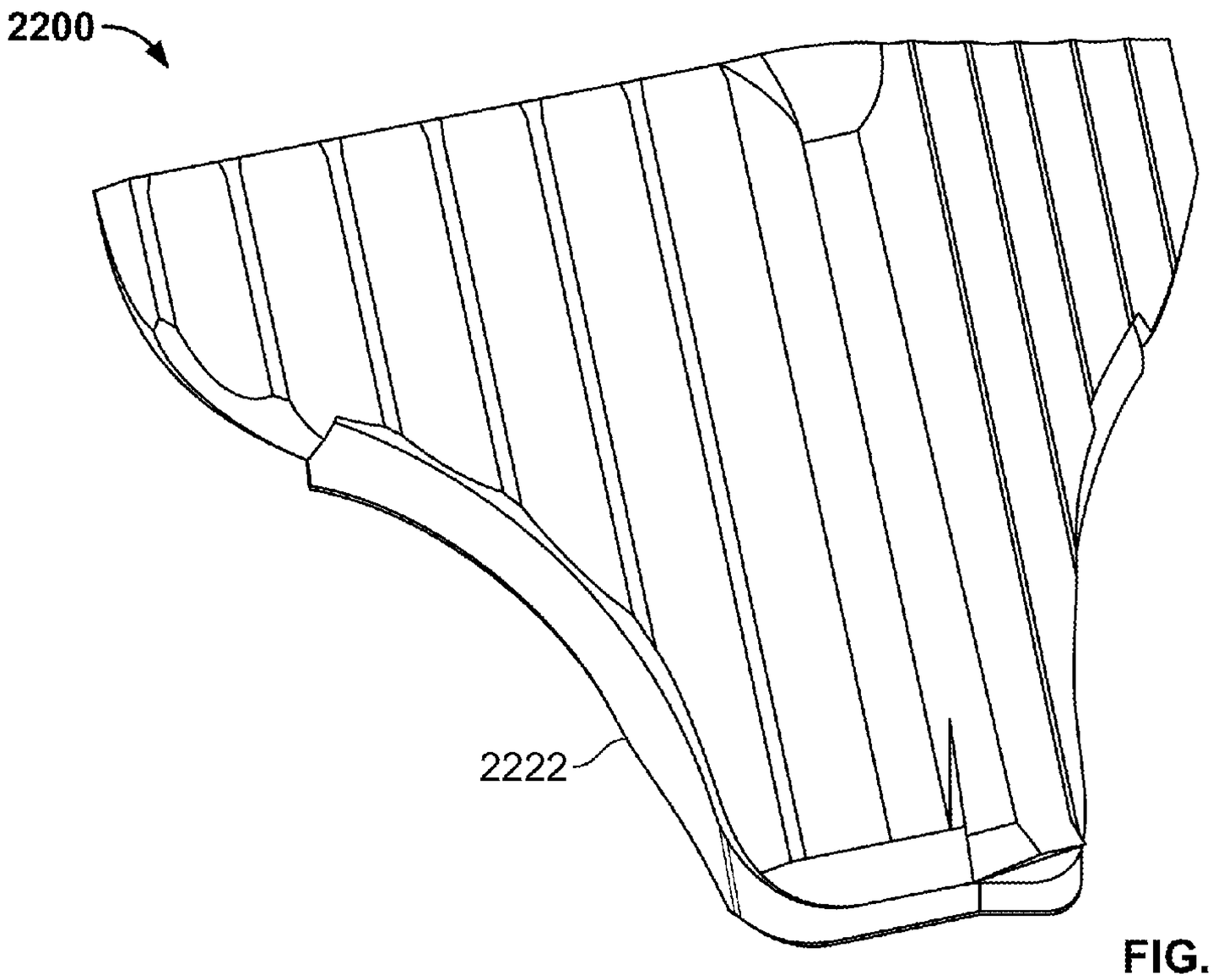

FIG. 38A

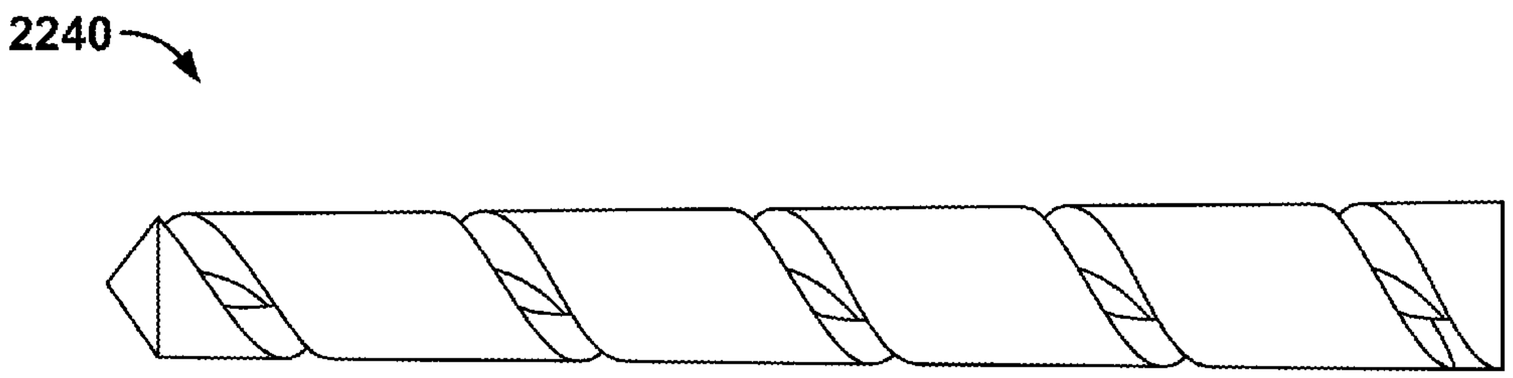

FIG. 38B

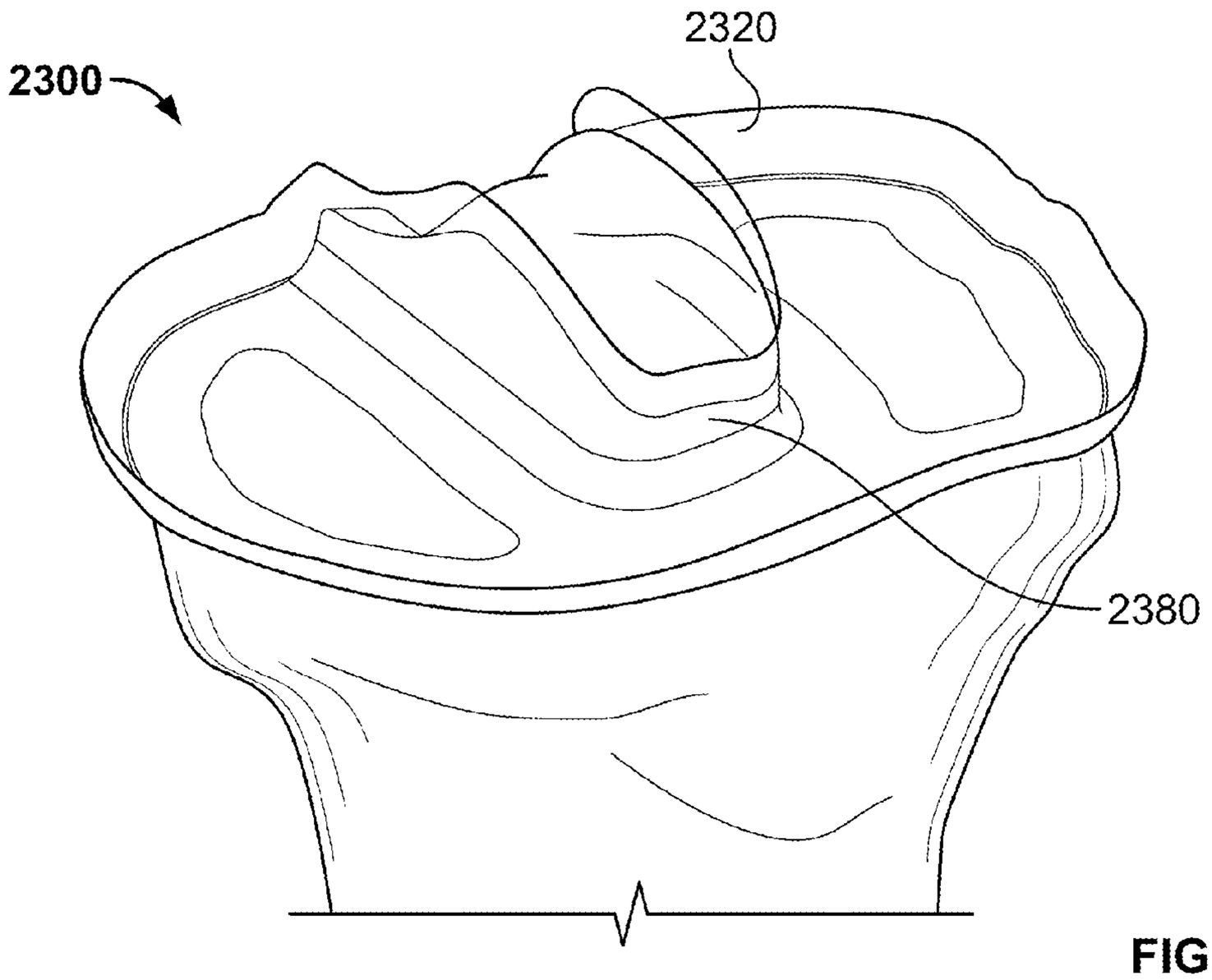

FIG. 39A

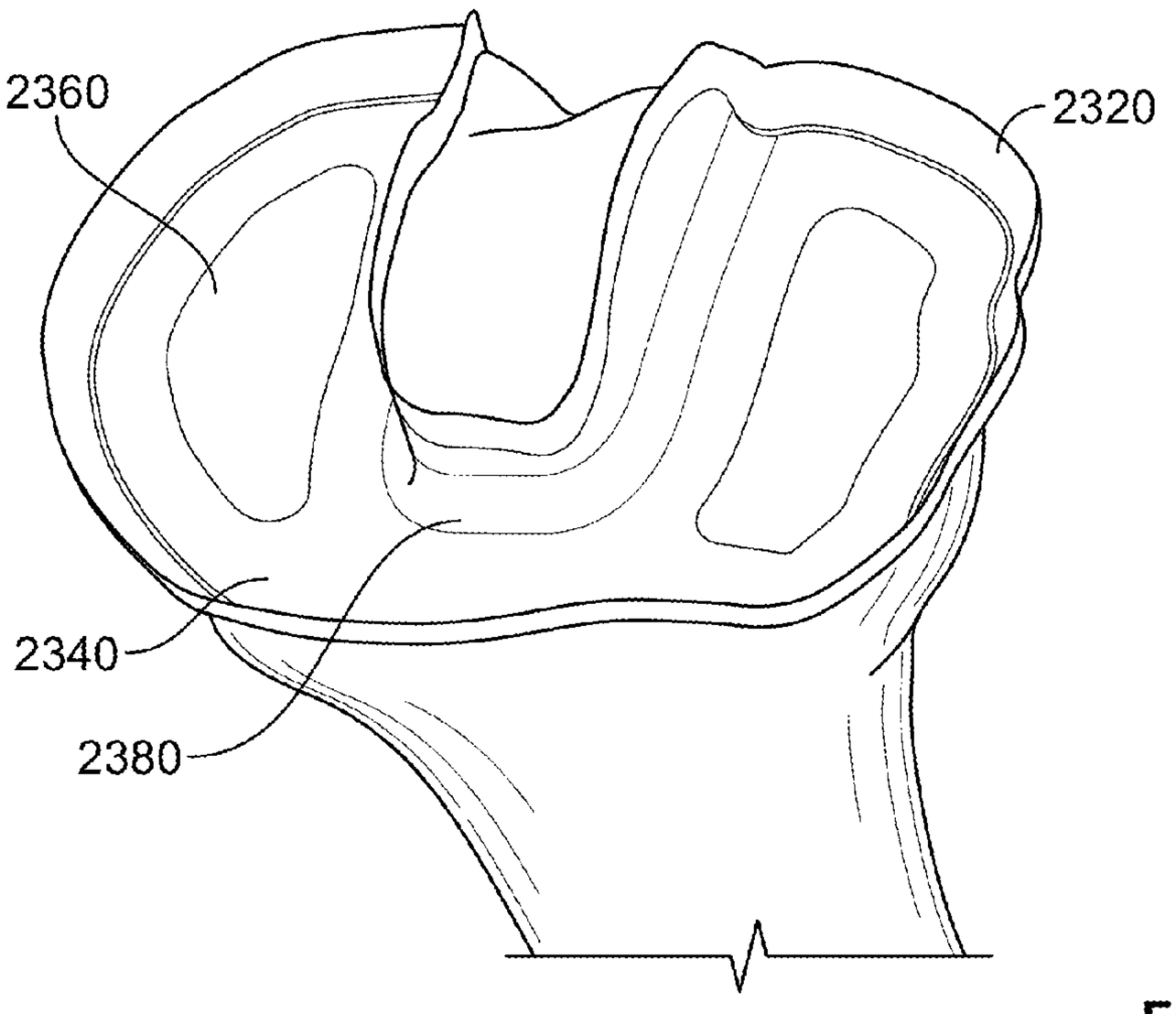

FIG. 39B

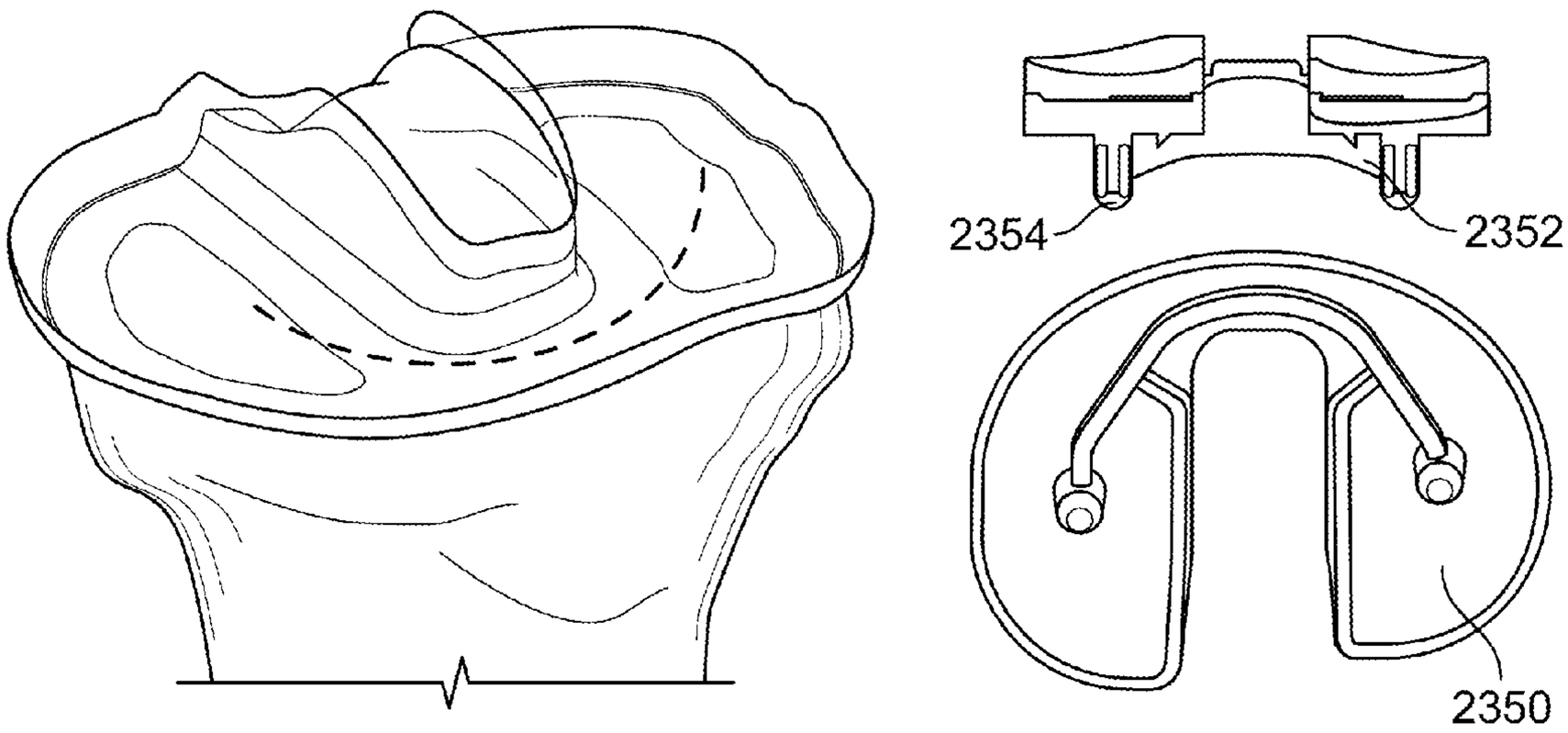

FIG. 39C

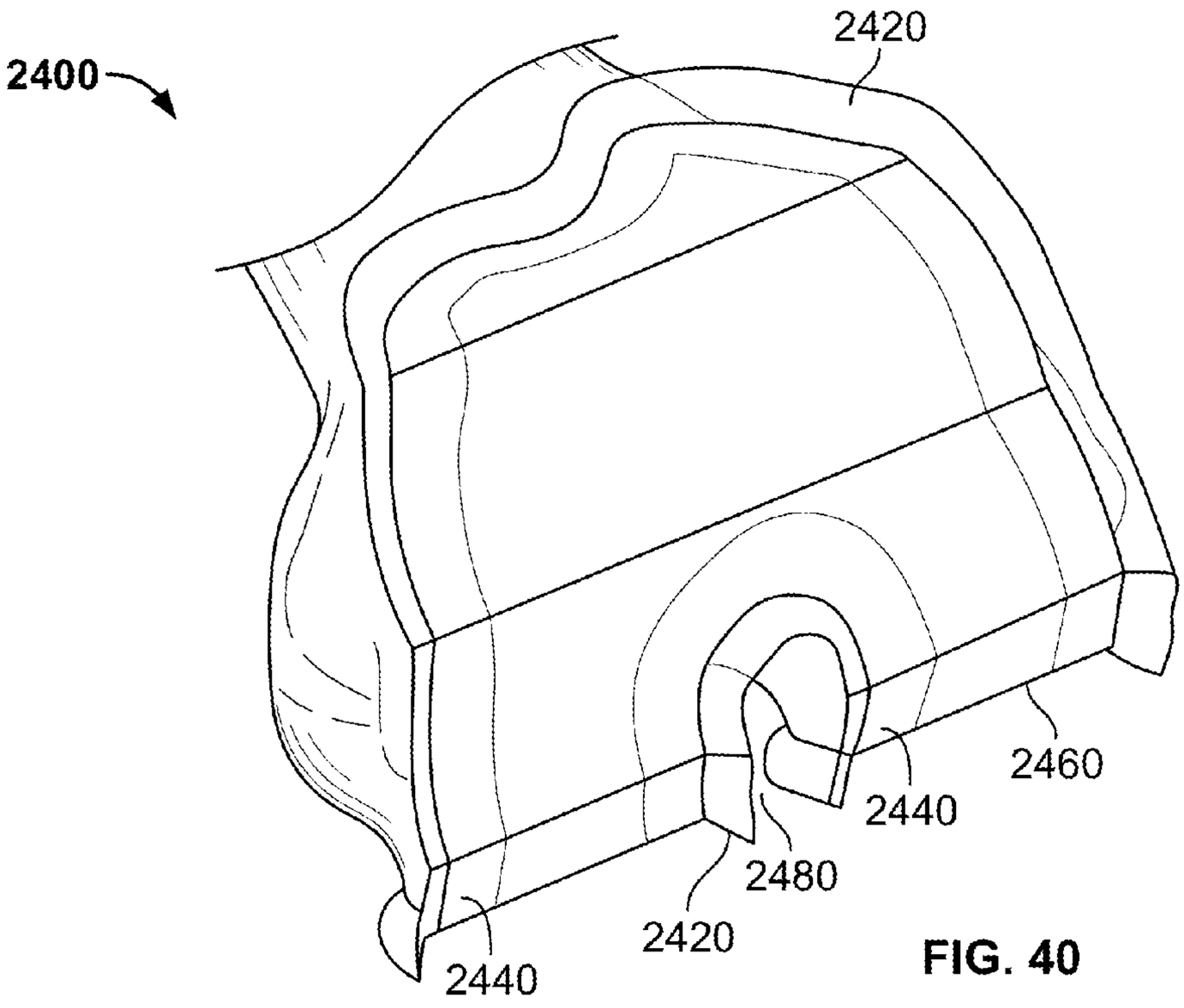

FIG. 40

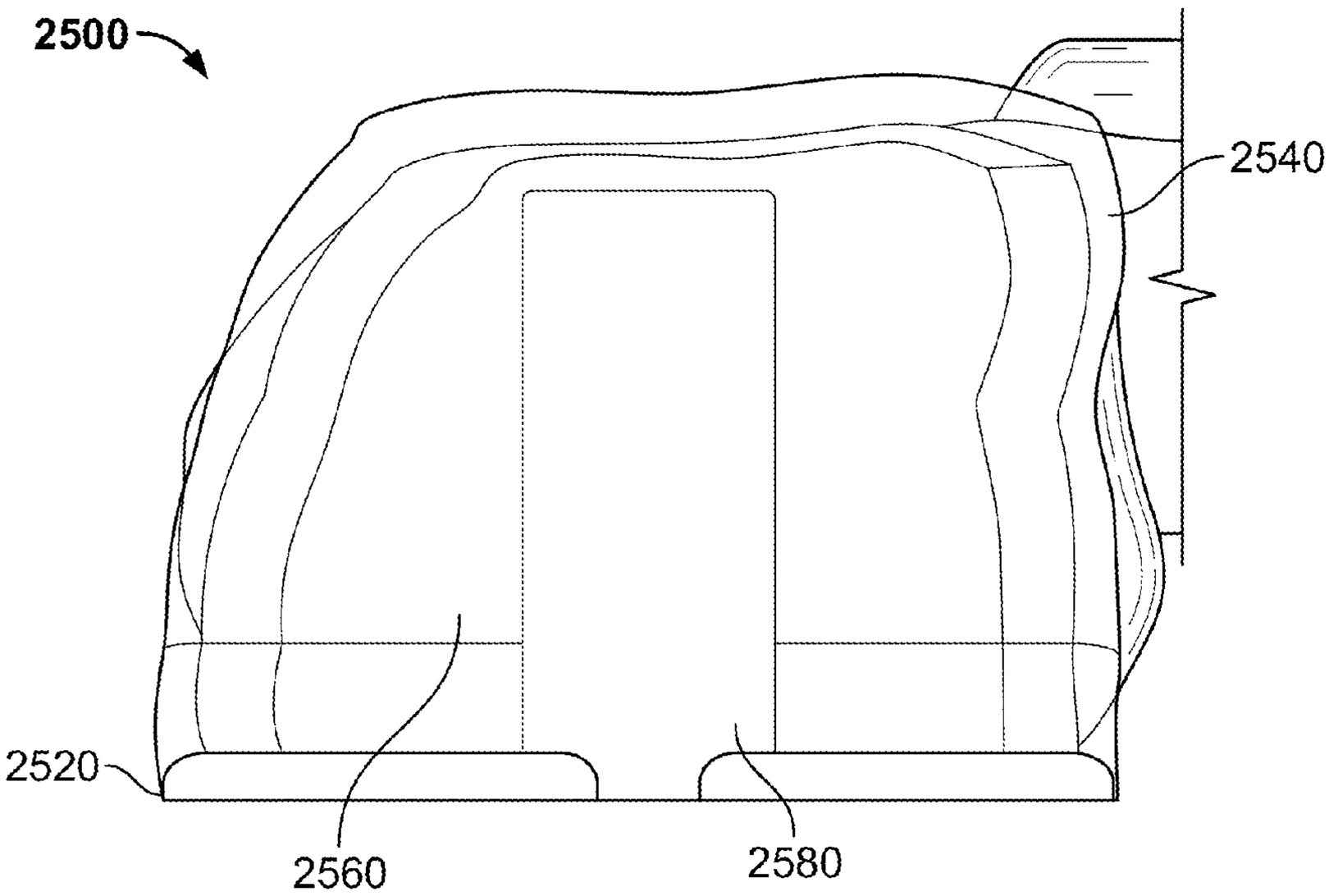

FIG. 41

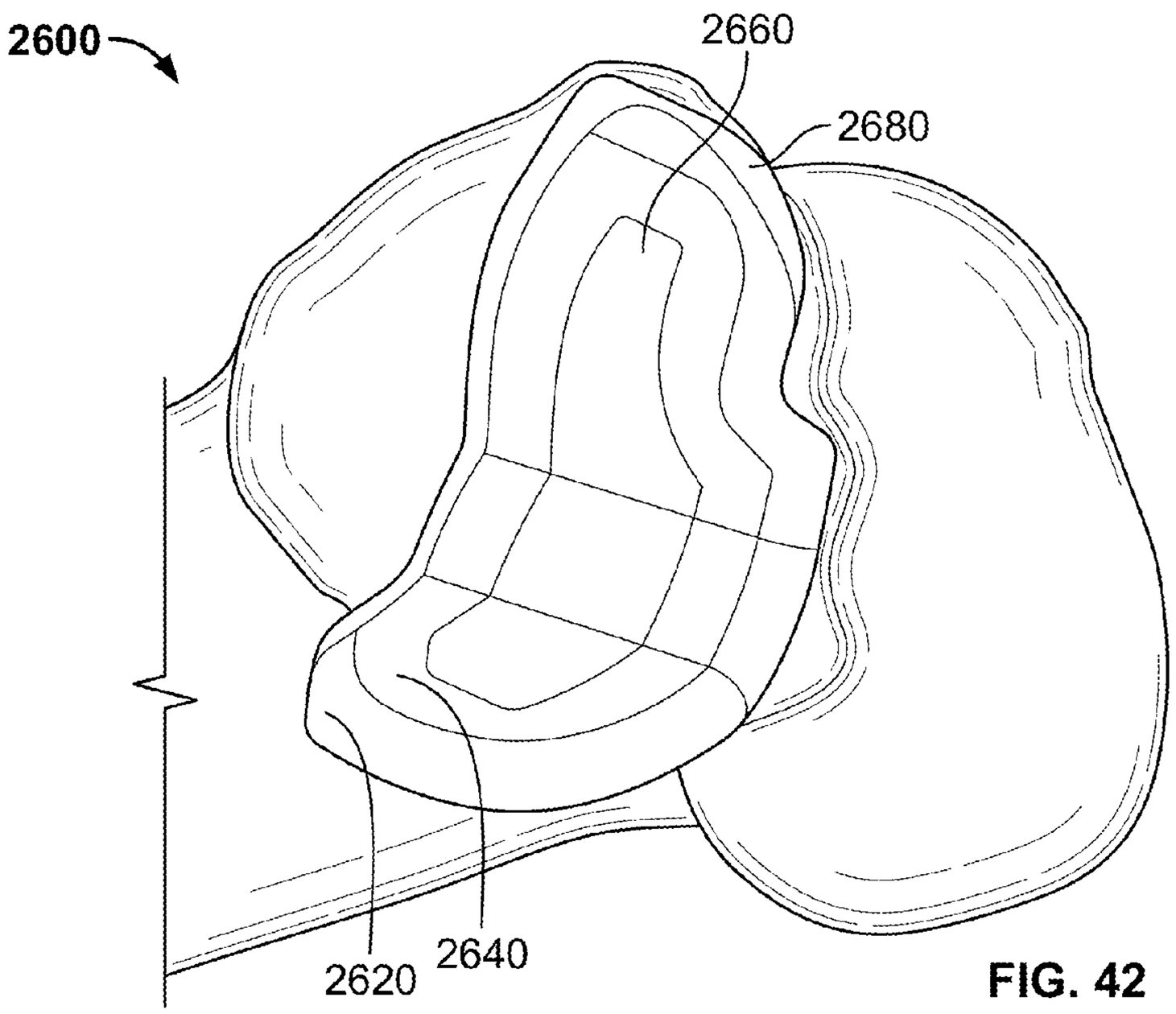

FIG. 42

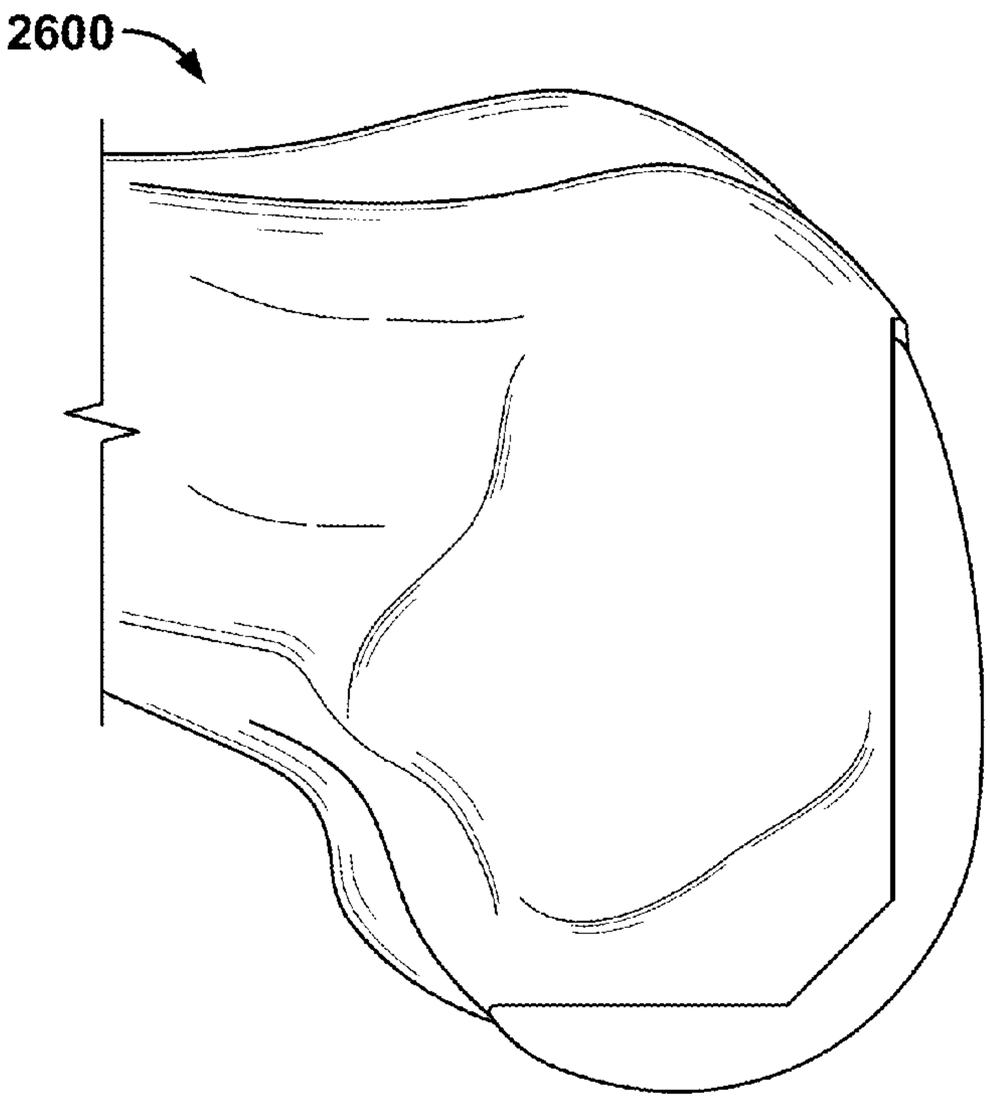

FIG. 43A

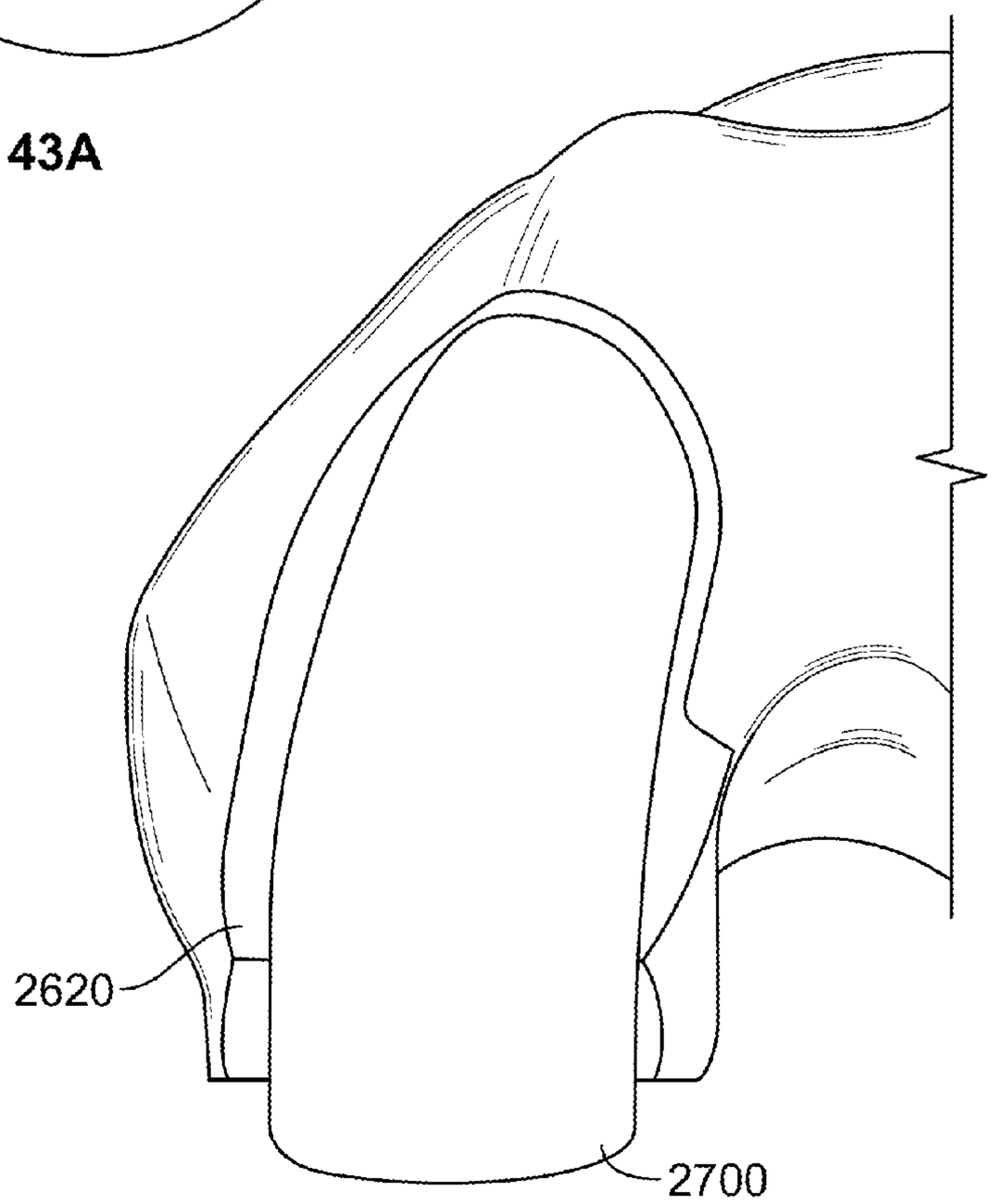

FIG. 43B

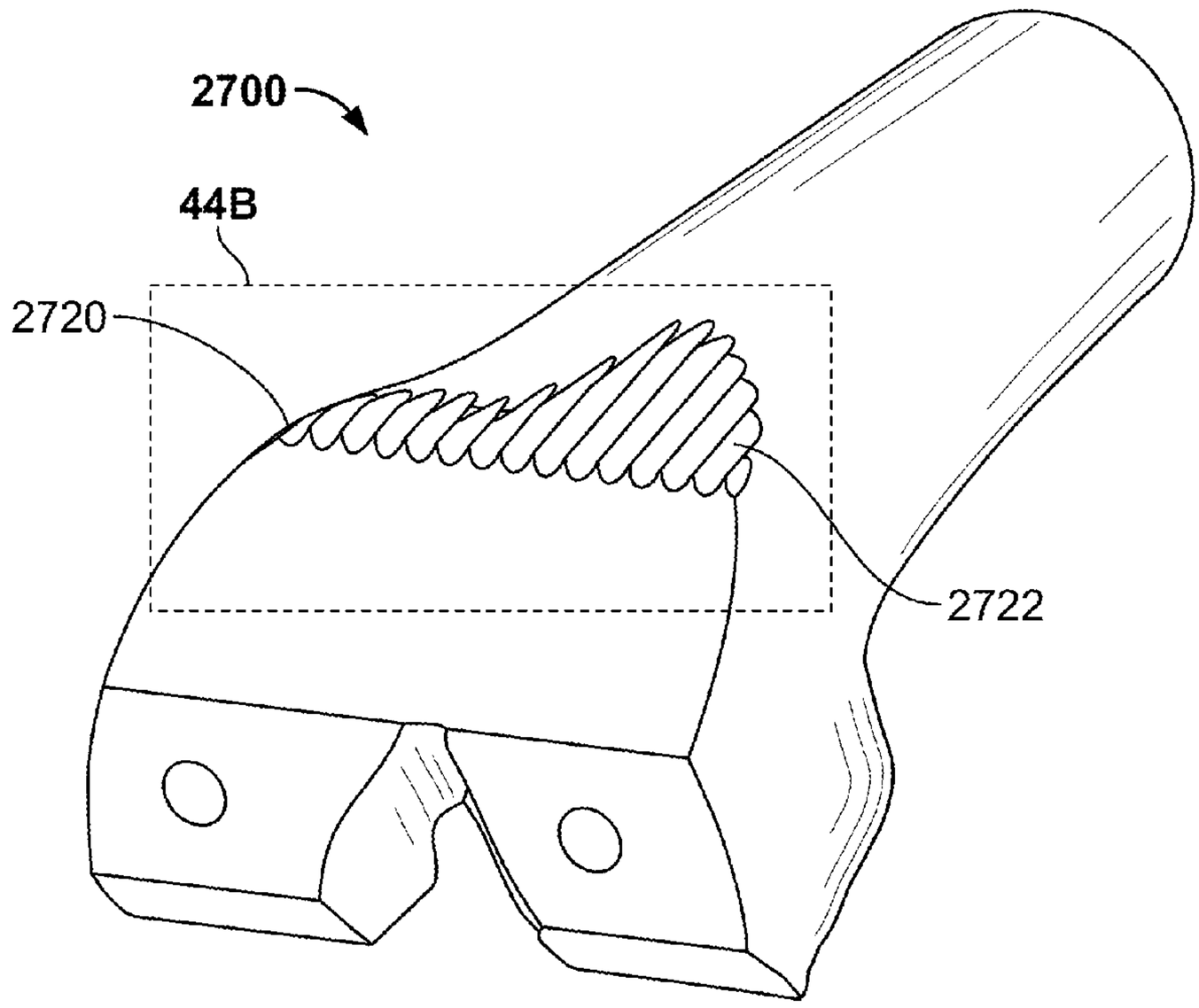

FIG. 44A

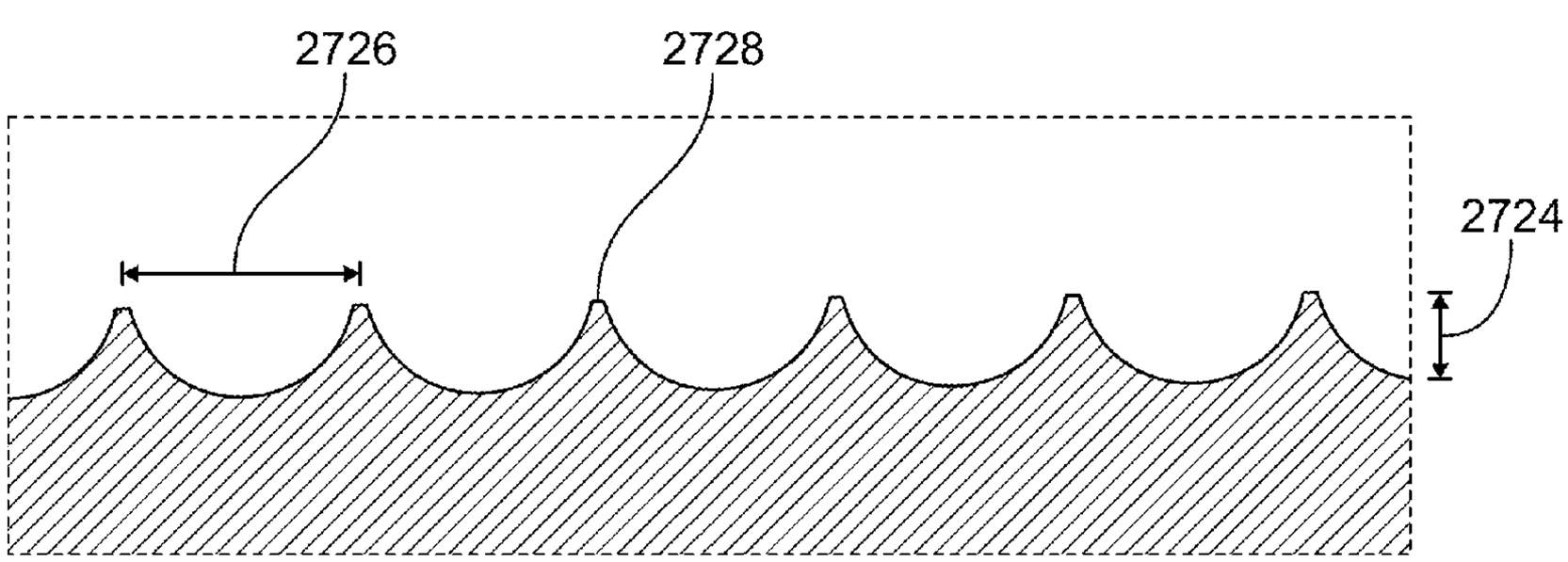

FIG. 44B

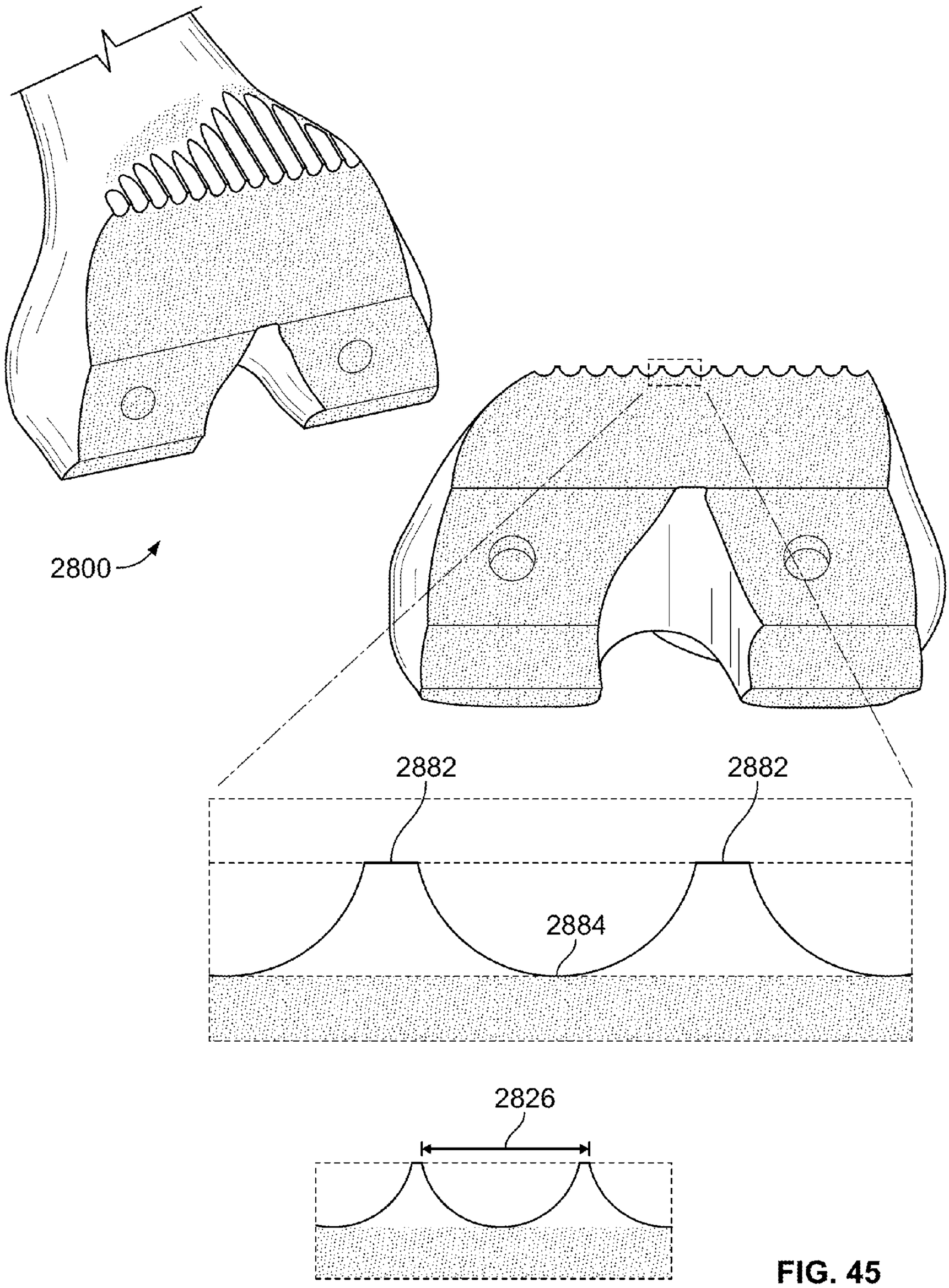

FIG. 45

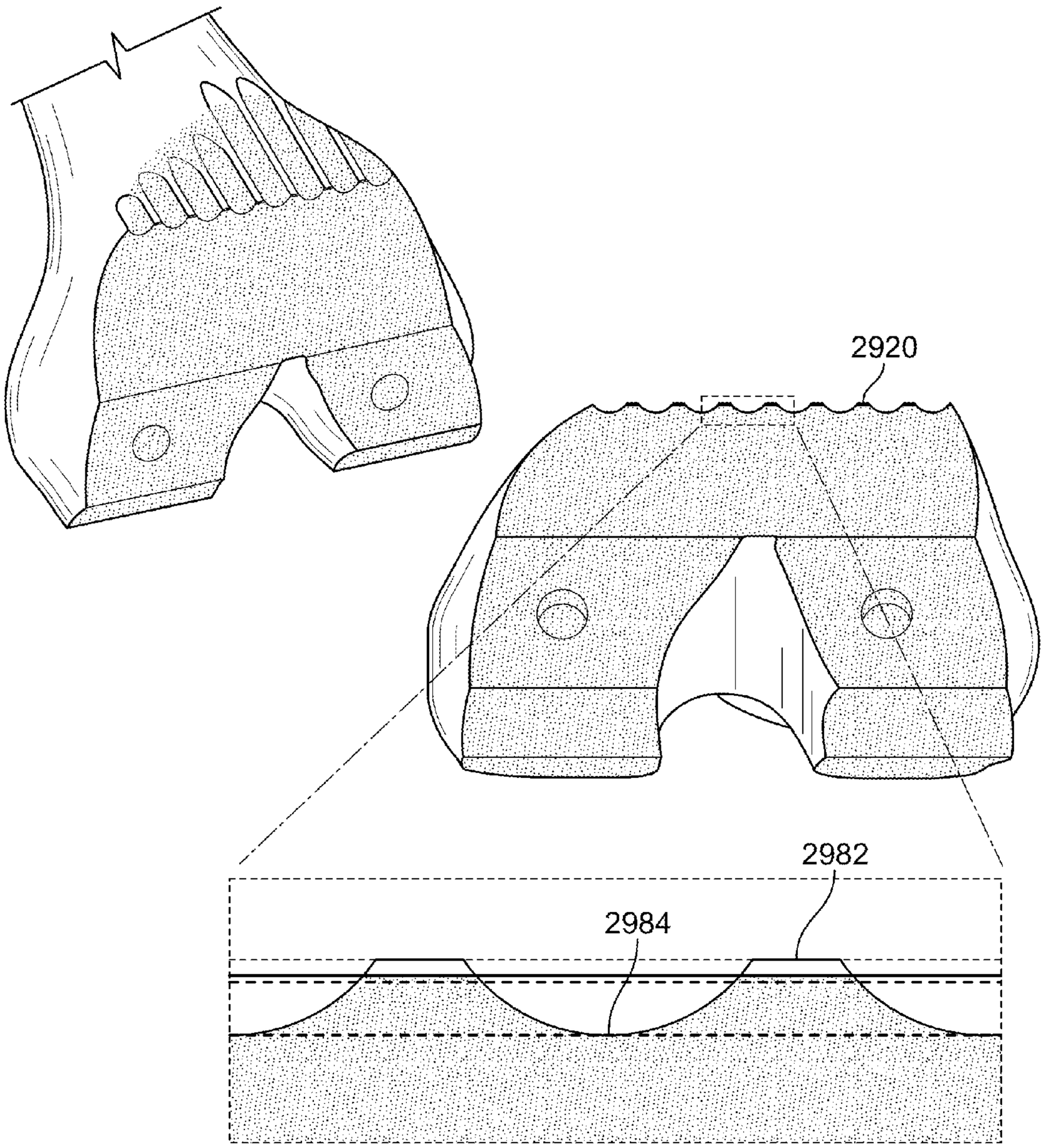

FIG. 46

BONE PADS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of the filing date of U.S. Provisional Patent Application No. 61/775,045, filed Mar. 8, 2013, the disclosure of which is hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

In a traditional knee arthroplasty surgery, the diseased bone and/or cartilage of a patient is generally removed and replaced with a prosthetic implant. A surgeon may prepare the bone using a hand-held oscillating saw blade, for instance, which generally results in a series of planar bone surface resections. Additionally, the surgeon may use a drill, broach or tamp instrument to make cylindrical holes into the bone to accommodate peg fixation features on the implant. The planar bone resections and cylindrical bone holes are generally oriented to interface with generally flat bone contacting surfaces and pegs of a prosthetic implant.

In such arthroplasty surgeries, the cartilage and/or bone of a patient may be prepared by a surgeon using conventional manual instrumentation. The instrumentation used may include, for example, planar resection guides, oscillating saws, drills, chisels, punches and reamers.

Robotic surgery may also be used in arthroplasty procedures, as well as in many different medical applications. The use of a robotically controlled bone preparation system allow for increased accuracy and repeatability of bone preparation. Rotational preparation instruments may be used during robotic surgery to prepare the bone and/or cartilage surfaces.

Bone preparation using these known methods generally provides surfaces of variable accuracy. Further, implant surfaces are generally prepared with the same level of consistency across the entire prepared bone surface. These methods of bone preparation may have a negative effect on the initial fixation of a cementless implant. If the surface does not provide a stable base for a cementless implant when initially fixed to the bone, the long term success of bone ingrowth/ongrowth onto the implant may be compromised due to micromotion, which may lead to fibrous ingrowth and subsequent bone resorption.

With advancements in robotically controlled bone preparation systems, bone preparation with specifically designed regions having increased levels of accuracy are now considered. Therefore, robotic bone preparation enables select aspects of the bone to be prepared at a generally more accurate and "tighter" tolerance compared with alternate methods of bone preparation. The degree of accuracy to which a prosthetic implant is implanted on a prepared or resected bone through robotic control depends on several factors. Among those factors include the tolerance to which the prosthetic implant is manufactured or know, the tolerance of any required tracking equipment used to position the robotic arm, and the tolerances of the robotic arm itself.

BRIEF SUMMARY OF THE INVENTION

The present invention includes bone preparation with designed areas having accurate tolerance profiles to enable improved initial fixation and stability for cementless implants and to improve long-term bone ingrowth/ongrowth

to an implant. Further, the present invention includes new methods of implanting an implant onto these accurate tolerance profiles.

A first aspect of the present invention is a method of preparing a bone surface to receive a prosthetic implant thereon, the prosthetic implant having an articular surface and a bone contacting surface. The method includes resecting the bone surface at a first location to create a first resected region having a first tolerance profile with a first cross-section. The method further includes resecting the bone surface at a second location to create a second resected region having a second tolerance profile with a second cross-section, the cross-section of the first tolerance profile being denser that the cross-section of the second tolerance profile. The method further includes contacting the bone contacting surface of the prosthetic implant with the first resected region.

In one embodiment of this first aspect the method further includes forming at least one recess in the bone surface prior to implanting the prosthetic implant on the bone surface, and inserting a retention element extending from the bone contacting surface in the at least one recess in the bone surface.

In another embodiment of this first aspect the method includes applying downward force to the articular surface of the prosthetic implant to compact bone in the first resected region.

In yet another embodiment of this first aspect the method includes resecting the bone surface at a plurality of locations to create a plurality of resected regions each having a tolerance profile with a cross-section, wherein the tolerance profile of each of the plurality of resected regions is denser that the cross-section of the second tolerance profile.

In still yet another embodiment of this first aspect the first of the plurality of resected regions is preferably located at an anterior aspect of the bone. The second of the plurality of resected regions is preferably located at an outer aspect of the bone. The third of the plurality of resected regions is preferably located at a posterior aspect of the bone.

In still yet another embodiment of this first aspect the cross-section of the tolerance profile of a first of the plurality of resected regions is less dense than the cross-section of the tolerance profile of a second of the plurality of resected regions and is more dense that the cross-section of the tolerance profile of a third of the plurality of resected regions.

In still yet another embodiment of this first aspect the tolerance profile of the second resected region is preferably ±0.010 inches and the tolerance profile of the plurality of resected regions is preferably ±0.025 inches. In other embodiments, the tolerance profile of the second resected region and plurality of resected regions may be more or less than ±0.010 inches and ±0.025 inches, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood on reading the following detailed description of non-limiting embodiments thereof, and on examining the accompanying drawings, in which:

FIG. **1** is a perspective view of an embodiment of the present invention of a prepared tibial bone surface with tolerance profiles.

FIG. **2** is a top view of the tibial bone surface with tolerance profiles from FIG. **1**.

FIG. **3** is a cross-sectional perspective view of another embodiment of the present invention of a prepared bone surface with tolerance profiles.

FIG. **4** is a front view of the perspective view shown in FIG. **3**.

FIG. **5** is a perspective view of an embodiment of a unicondylar tibial implant.

FIG. **6** is a top view of another embodiment of the present invention of a prepared tibial bone surface with tolerance profiles.

FIG. **7** is a perspective view of another embodiment of the present invention of a tolerance profile.

FIG. **8** is a cross-sectional view taken along line B-B of the tolerance profiles shown in FIG. **7**.

FIG. **9** is a cross-sectional view of another embodiment of the present invention of a tolerance profile.

FIG. **10** is a perspective view of one embodiment of the present invention of a prepared femoral bone with tolerance profiles.

FIG. **11** is a view from a posterior aspect of the prepared femoral bone with tolerance profiles shown in FIG. **10**.

FIG. **12** is a view of a distal bone contacting surface of a unicondylar femoral implant.

FIG. **13** is a view of a posterior bone contacting surface of the unicondylar femoral implant from FIG. **12**.

FIG. **14** is a side view of the unicondylar femoral implant of FIG. **12**.

FIG. **15** is a top view of a tibial bone surface showing yet another embodiment of the present invention of tolerance profiles.

FIG. **16** is a top view of another embodiment of the present invention of a prepared tibial bone.

FIG. **17** is a perspective view of a distal femur having a plurality of planar resections and a box cut with radiused edges.

FIG. **18**A is a perspective view of one embodiment of a resected medial portion of a proximal tibia.

FIG. **18**B is a front plan view of the a resected medial portion shown in FIG. **18**A.

FIG. **19**A is a perspective view of another embodiment of a resected medial portion of a proximal tibia.

FIG. **19**B is a front plan view of the a resected medial portion shown in FIG. **19**A.

FIG. **20**A is a perspective view of one embodiment of a resected portion on medial and lateral sides of a proximal tibia.

FIG. **20**B is a front plan view of the resected portion on medial and lateral sides of a proximal tibia shown in FIG. **20**A.

FIGS. **21**A-**24**C show varying prepared keel slot depths in the proximal tibia.

FIG. **25**A is a plan view of one embodiment of a keel punch.

FIG. **25**B is a cross-section of the punch portion of the keel punch shown in FIG. **25**A taken along line **2-2**.

FIG. **26**A is a cross-section of another embodiment of a punch portion of a keel punch adjacent the proximal end of the punch portion.

FIG. **26**B shows the difference in cross-section between a 3 mm burr straight cut and the cross-section of the portion of the punch portion of the keel punch shown in FIG. **26**A.

FIG. **26**C shows the difference in cross-section between a 3 mm burr wave cut and the cross-section of the portion of the punch portion of the keel punch shown in FIG. **26**A.

FIG. **27**A is an example of a cross-section of another embodiment of a punch portion of a keel punch adjacent the proximal end of the punch portion.

FIG. **27**B is a cross-sectional view at Section **1-1** of FIG. **27**A of a 2.5 mm burr straight cut in relation to a major striation of the keel punch of FIG. **27**A.

FIG. **27**C is a cross-sectional view at Section **2-2** of FIG. **27**A of the 2.5 mm burr straight cut in relation to the minor striation of the keel punch of FIG. **27**A.

FIGS. **28**A-**28**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and a 2.5 mm burr wave cut.

FIGS. **29**A-**29**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and a 2.0 mm burr wave cut.

FIGS. **30**A-**30**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and a 2.0 mm burr double wave cut including a first wave cut and a second wave cut.

FIGS. **31**A-**31**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and successive 2.5 mm burr plunge cuts located at each major striation of tibial prosthesis keel and a 1.5 mm burr straight cut.

FIGS. **32**A-**32**C are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and successive 2.5 mm burr plunge and drag cuts.

FIGS. **33**A-**33**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and successive 2.5 mm burr plunge cuts.

FIGS. **34**A-**34**B are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and successive 2.0 mm burr plunge cuts.

FIGS. **35**A-**35**C are examples of a transverse cross-section of a tibial prosthesis keel, a punch portion of a keel punch, and successive 2.0 mm burr plunge diamond cuts each including first, second, third and forth plunge cuts.

FIG. **36**A is a perspective view of a punch portion of a keel punch with successive 2.5 mm drilled holes and 2.0 mm burr plunge cuts in between each 2.5 mm drilled holes following the path of an outer perimeter surface of the punch portion.

FIGS. **36**B-**36**C are examples of a transverse cross-section of the tibial prosthesis keel, the punch portion of the keel punch, and the 2.5 mm drilled holes and 2.0 mm burr plunge cuts in between each 2.5 mm drilled holes.

FIG. **37**A is a perspective view of a punch portion of a keel punch with successive 2.5 mm drill pivot cuts following the path of an outer perimeter surface of the punch portion.

FIG. **37**B is one embodiment of the angles between cuts in a 2.5 mm drill pivot cut.

FIGS. **37**C-**37**D is an example of a transverse cross-section of the tibial prosthesis keel, the punch portion of the keel punch, and the 2.5 mm drill pivot cuts.

FIG. **38**A is a perspective view of an embodiment of a tibial prosthesis keel having a custom keel shape around a portion of an outer perimeter thereof.

FIG. **38**B is an embodiment of a 0.5° drafted end mill.

FIGS. **39**A-**39**B are perspective views of the proximal tibia after bicruciate retaining debulking and finishing is performed.

FIG. **39**C shows a tibial implants having a keel and pegs configured to be retained within a slot machined into proximal tibia prepared surface shown in FIGS. **39**A-**39**B.

FIGS. **40**, **41** and **42** are perspective views of the distal femur after different debulking and finishing procedures are performed.

FIG. **43**A is a side view and FIG. **43**B is a plan view of an unicondylar prosthesis on the partial knee resurfacing region of FIG. **42**.

FIG. **44**A shows a distal femur including a tolerance profile or ribs extending along an anterior bone cut surface.

FIG. **44**B shows a cross-sectional view of the ribs of FIG. **44**A.

FIG. **45** shows a distal femur with an MMC implant profile.

FIG. **46** shows a distal femur with a LMC implant profile.

DETAILED DESCRIPTION

As used herein, the term "distal" means more distant from the heart and the term "proximal" means closest to the heart. The term "inferior" means toward the feet and the term "superior" means towards the head. The term "anterior" means towards the front part of the body or the face and the term "posterior" means towards the back of the body. The term "medial" means toward the midline of the body and the term "lateral" means away from the midline of the body.

FIG. **1** illustrates a perspective view of a tibial bone **10**. Bone **10** includes an unprepared region **11**, a sagittal surface **15** and a transverse surface **20**. Region **11** preferably retains unaltered or non-resected patient anatomy, which may include, for example, one or more of the following: articular cartilage, meniscus, and anterior and posterior cruciate ligament insertion regions. Sagittal surface **15** and transverse surface **20** represent cartilage/bone that have been prepared for an orthopedic procedure such as, for example, a partial knee resurfacing or unicondylar procedure. While many different types of prosthetic implants may be implanted on transverse surface **20**, prosthetic implants disclosed in U.S. Ser. No. 61/500,257 titled "Prosthetic Implant and Method of Implantation" are particularly suited for implantation thereto the disclosure of which is hereby incorporated by reference herein in its entirety. In the embodiment shown, sagittal surface **15** has a generally perpendicular angular relationship to transverse surface **20**. An outer bone edge **16** extends from an anterior aspect **12** of sagittal surface **15** to a posterior aspect **13** of sagittal surface **15**, thus defining an outer-most edge **14** for transverse surface **20**.

Transverse surface **20** is comprised of an anterior zone **21**, an outer zone **22**, a posterior zone **23** and an internal zone **24**. As shown, anterior zone **21** is adjacent to sagittal surface **15**, internal zone **24** and bone edge **16**. FIG. **2**, which illustrates a top view of tibial bone **10**, shows that anterior zone **21** has generally linear contact geometry **25** with sagittal surface **15** and non-linear contact geometries with bone edge **16** and interior zone **24**. Linear contact geometry **25** approximately occupies preferably less than 33 percent of the outer profile of anterior zone **24**, as shown from this top view. In other embodiments, linear contact geometry occupies between 10 and 50 percent of the outer profile of anterior zone **24**, and in other embodiments occupies less than 10 and more than 50 percent of the outer profile of anterior zone **24**.

As shown in FIGS. **1** and **2**, both outer zone **22** and posterior zone **23** are adjacent to interior zone **24** and bone edge **16**. Outer zone **22** is located along bone edge **16** between anterior zone **21** and posterior zone **23**; however, the majority of the area of outer zone **22** is shifted closer toward posterior zone **23**. This posterior shift of zone **22** is functionally important because the contact region between a femoral unicondylar implant and tibial unicondylar implant is generally shifted posteriorly throughout full range of leg motion. Outer zone **22** therefore may be shifted posteriorly from its position as shown in FIG. **2**.

As further shown in FIG. **2**, anterior zone **21**, outer zone **22** and posterior zone **23** comprise approximately 40 percent of the area of transverse surface **20**. Therefore, interior zone **24** comprises approximately 60 percent of the area of transverse surface **20**. In other embodiments, zones **21**, **22** and **23** comprise more or less that 40 percent of the area of transverse surface **20**, while zone **24** comprises more or less than 60 percent of the area of transverse surface **20**. Further, the respective areas of anterior zone **21** and posterior zone **23** are substantially equivalent and greater than the area of outer zone **22**. In the embodiment shown, the combination of the areas of anterior zone **21** and posterior zone **23** occupy approximately 30 percent of the area of transverse surface **20**.

Anterior zone **21**, outer zone **22** and posterior zone **23** have a substantially equivalent surface texture, which is generally represented as a tolerance profile **30** as shown in FIG. **3**. The three-dimensional geometry of tolerance profile **30** is the result of a rotational cutting tool, such as a burr for example, making a plurality of channeled preparations **31** into tibial bone **10**. In the embodiment shown, the plurality of channeled preparations **31** follow a substantially linear path. As shown in FIG. **4**, tolerance profile **30** has a height **32**, a width **36** and a plurality of protrusions **33**. Height **32** is essentially the distance from the most distal bone preparation **34** made with the cutting tool to the highest relative peak **35** of the bone. In other words, height **32** may be described as the planar distance between peak **35** and trough **34** of one of the channeled preparations **31**. Tolerance profile **30** is preferably designed to be very accurate, or "tight". Therefore, height **32** for all protrusions **33** are substantially consistent from protrusions **33** to adjacent protrusion **33**.

Width **36** of the plurality of channel preparations **31** is defined as the distance from bone peak **35** to adjacent peak **35** in a transverse direction. Similar to the accuracy requirements for height **32**, width **36** is designed to be consistent and accurate within respective zones **21**, **22** and **23**. Further, the tolerance profile **30**, including the distal bone preparation **34** to peak **35** distance, must be substantially equivalent relative to anterior zone **21**, outer zone **22** and posterior zone **23**. Alternately described, the proximal-distal location relative tibial bone **30** must be accurate for respective zones **21**, **22** and **23**.

Interior zone **24** has a tolerance profile **40**, also illustrated in FIGS. **3** and **4**. The three-dimensional geometry of tolerance profile **40** is the result of a rotational cutting tool, such as a burr, making a plurality of channeled preparations **41** which follow substantially linear paths. In this embodiment, the same rotational cutting tool is used to prepare tolerance profile **30** and tolerance profile **40**. Tolerance profile **40** has a height **42** as measured from the most distal bone preparation **44** to the highest relative peak **35** for a plurality of protrusions **43**. In other words, height **42** may be described as the planar distance between peak **45** and trough **44** of one of the channeled preparations **41**. Tolerance profile **40** also has a width **46** as measured from peak **35** to adjacent peak **35** in a transverse direction. Tolerance profile **40** is not required to be as accurate, or "tight", as the tolerance profile **30** for zones **21**, **22** and **23**. As show in FIGS. **3** and **4**, tolerance profile **30** has a denser cross-section than that of the cross-section of tolerance profile **40**.

Alternately described, height **42** and width **46** of profile **40** are larger than height **33** and width **36** of profile **30**. Further, there is a lesser requirement for consistency from protrusion **43** to protrusion **43** for profile **40** that for the respective protrusion **33** to protrusion **33** consistency in profile **30**. Simply stated, the preparation for interior zone **24** may be performed faster, with less rotational instrument passes across the bone, and with less accuracy than for anterior zone **21**, outer zone **22** and posterior zone **23**.

The cartilage and/or bone of tibial bone **10** may be prepared with the assistance of a robot. Robot assisted bone preparation may include: implant specific software, saw cutting, milling/burring or other rotational cutting instruments and various levels of surgeon interface. For example, in a first robot mode, the robot may perform the cartilage/bone preparation with the surgeon observing. In such a mode, the surgeon may not have any control over the movement of the robot or may instead be controlling the movement of the robot remotely. In a second robot mode, the surgeon may actually guide a rotational cutting tool within a predetermined boundary. In the second mode, the implant specific software is preferably programmed within the robot, which establishes boundary constraints for the preparation. Here, the surgeon will not be able to extend the preparation outside of a specific boundary. For the bone preparation shown, the surgeon preferably uses a combination of both the first and second robot modes and uses a burr as the cutting tool. In both the first and second robot modes, the surgeon would be able to stop the robotic preparation if necessary. Such robotic technology that may be applied for use with the present invention includes that described in U.S. Pat. Nos. 6,676,669, 7,892,243, 6,702,805, and 6,723,106 as well as U.S. Patent Application Nos. 2010/0268249, 2008/0202274, 2010/0268250, 2010/0275718, and 2003/0005786, the disclosures of which are all hereby incorporated by reference in their entireties.

Once the bone is prepared as previously described, the prosthetic tibial implant **50**, shown in FIG. **5**, may be implanted on the prepared bone surface. Implant **50** is a modular style, unicondylar design that has a proximal surface **51** and a distal surface **52**. The modular style indicates that a separate polyethylene insert (not shown) is assembled to proximal surface **51**. Distal surface **52** is designed for cemented or cementless fixation to the bone and includes a porous ingrowth/ongrowth structure such as beads or a porous metal structure. An example of a beaded ingrowth structure is described in U.S. Pat. No. 4,550,448, the disclosure of which is hereby incorporated by reference herein in its entirety. The porous metal structure may be manufactured from the technology described in U.S. Pat. No. 7,537,664, U.S. Patent Application No. 2006/0147332, U.S. Pat. No. 7,674,426, U.S. Patent Application No. 2006/0228247 and U.S. Pat. No. 7,458,991, the disclosures of which are all hereby incorporated by reference in their entireties.

Implant **50** is implanted onto tibial bone **10** by initially contacting peaks **35** of anterior zone **21**, outer zone **22** and posterior zone **23**. After implant **50** has established contact, a force is applied to proximal surface **51**. The applied force results in the compaction of the plurality of protrusions **33** until the implant reaches the final seating location on distal bone preparation **34**. The compaction of bone preferably has an improved biologic effect on the biologic ingrowth/ongrowth process. When implant **50** is seated in a final location, the implant is preferably contacting anterior zone **21**, outer zone **22**, posterior zone **23** and sagittal surface **15**. Contact with respect zones **21**, **22** and **23** preferably results in an accurate and stable surface for the implant **50** because of the accuracy of tolerance profile **30**. In the embodiment shown, implant **50** is not in contact with interior zone **24**; however, the distance between distal surface **52** and peaks **45** will be at a distance conducive to future bone ingrowth/ongrowth.

FIG. **6** shows an alternate embodiment of a prepared tibial bone **110** having a transverse surface **120** including an anterior zone **121**, an outer zone **122**, a posterior zone **123**, an interior zone **124**, a sagittal surface **115** and a bone edge **116**. Both anterior zone **121** and posterior zone **123** are adjacent to sagittal surface **115**, bone edge **116** and interior zone **124**. While sagittal surface **115** may have a substantially perpendicular relationship with transverse surface **120**, surface **115** may also have a non-perpendicular relationship with surface **120**. Outer zone **122** is preferably adjacent to both interior zone **124** and bone edge **116**. The geometry for zones **121**, **122**, **123** and **124** may be any combination of linear or non-linear geometries as previously described. It is understood that each zone may have a unique geometry, or alternatively, each zone may have zone geometries that are substantially similar, or any other combination thereof. In the embodiment shown, respective zones **121**, **122** and **123** occupy approximately 50 percent of prepared transverse surface **120**. Therefore, interior zone **124** also occupies approximately 50 percent of prepared transverse **120**. In other embodiments, zones **121**, **122** and **123** comprise more or less that 50 percent of the area of transverse surface **120**, while zone **124** comprises more or less than 50 percent of the area of transverse surface **120**. As shown, the percent area of coverage is substantially equivalent for zones **121**, **122** and **123**. Any tolerance profiles are consistent with that previously described for all zones.

In yet other embodiments, which are not shown, the range of coverage for the combination of the anterior zone, outer zone and posterior zone may range between 10 and 90 percent. In still yet other embodiments, the range or coverage for the combination of the anterior, outer and posterior zones may be less than 10 percent or more than 90 percent. Further, the range of coverage for the anterior zone, outer zone, posterior zone may be substantially similar, different, or any combination thereof. In all embodiments, the tolerance profiles are consistent with that previously described for all zones.

FIG. **7** shows a perspective view of an alternate embodiment of the geometry of a tolerance profile **130** that may be applied to any of the anterior, outer, posterior or interior zones previously described. Here, the three dimensional geometry of tolerance profile **130** is essentially a sinusoidal or pyramid-like pattern consisting of a plurality of peaks **135** and plurality of distal bone preparations **134**. A cross-sectional side view of the preparation is illustrated in FIG. **8**. Regarding FIGS. **7** and **8**, the geometry may be accomplished by a series of generally linear passes of a rotational cutting instrument, followed by a series of generally orthogonal rotational cutting instrument passes. In another embodiment, the relationship between cutting instrument passes may be at a non-orthogonal angle. In yet other embodiments, the cutting path for the rotational cutting instrument may be circular, or any other non-linear path, or any combination of linear and non-linear paths.

FIG. **9** shows a cross-sectional view of another embodiment of the geometry of a tolerance profile for any of, or any combination of tolerance profiles for anterior, outer, posterior or interior zones. Here, the general shape of protrusions **233** is substantially rectangular. It is envisioned that in yet other embodiments, a rotational cutting tool may take multiple cutting paths resulting in many geometrical shapes such as circular, square, trapezoid or any other linear or non-linear geometries.

FIG. **10** illustrates a view of the distal aspect of a femoral bone **310** and FIG. **11** illustrates a view of the posterior aspect of femoral bone **310**. Here, femoral bone **310** has been prepared to receive a unicondylar femoral implant (not shown). Consistent with that previously described, the bone is prepared using a rotational cutting tool guided by a surgeon, robot, or combination thereof. Femoral bone **310**

includes an anterior zone **321**, an outer zone **322**, a posterior zone **323** and an interior zone. Zones **321**, **322** and **323** share a substantially similar tolerance profile **330** (not shown). Interior zone **324** has a tolerance profile **340** (not shown) which is different than profile **330**. Profile **330** is designed as a more accurate and "tighter" tolerance compared with profile **340**. The methods of implantation are also consistent with that previously described.

FIGS. **12-14** illustrate an embodiment of a unicondylar femoral component **400** having an articular surface **420** and a bone contacting surface **424**. Here, the implant includes an anterior zone **421**, an outer zone **422** and a posterior zone **423** designed to mate with the prepared femoral bone, such as previously described. Zones **421**, **422** and **423** may have any geometry, or combination of geometries such as: spherical indentations, generally cylindrical indentations, sinusoidal, or other geometry. The concept is that zones **421**, **422** and **423** would be manufactured with a tighter degree of tolerance as compared with other aspects of the implant. Further, the specific geometry of these respective zones is designed to improve secure initial fixation to the prepared bone surface and promote ingrowth/ongrowth.

Another aspect of the present invention is to apply a bone adhesive to the interior zone of the bone preparation or to an interior zone of an implant component. An example of a medical adhesive is described in U.S. Patent Application Nos. 2009/0318584, 2009/0280179, and 2010/0121459, the disclosures of which are hereby incorporated by reference herein in their entirety. In this aspect of the present invention, the bone adhesive would provide initial fixation to an interior zone, which is prepared to a larger tolerance profile, but will preferably resorb over time allowing for bone ingrowth/ongrowth.

FIG. **15** shows a prepared tibial bone surface with an alternate tolerance profile pattern. Here, tibial bone has an anterior end **501**, a posterior end **502**, a sagittal surface **515** and an outer edge **516**. The bone is prepared to three different tolerance zones: peripheral zone **521**, posterior zone **522** and anterior zone **523**. These three tolerance zones are each prepared to different levels of tolerance accuracy. For example, peripheral zone **521** is prepared to be the more accurate zone of the three tolerance zones. Anterior zone **523** is prepared to be the least accurate tolerance zone and has a surface area percentage less than anterior zone **523**. Posterior zone **522** has an accuracy ranging between respective zones **521** and **523**. As a specific example, peripheral zone **521** has a tolerance of ±0.010 in, posterior zone **522** has a tolerance of +0.010/−0.025 in, and anterior zone **523** has a tolerance of ±0.025 in.

The known anatomy of the proximal end of a tibial bone is that the periphery, or outer region, of the bone is cortical bone and the interior regions are cancellous bone. Regions of the cancellous bone may have different densities. For example, the cancellous bone in the posterior regions of the proximal tibial may be denser than bone in the anterior region of the cancellous bone. This may be the result of increased loading of this region of the proximal tibia, and via wolf's law, bone is remodeled in response to the increased loading.

Tolerance zones **521**, **522** and **523** of FIG. **15** are now further described with respect to the anatomy of a proximal tibial bone **500**. Peripheral zone **521** substantially covers cortical bone which extends along outer edge **516**. In this embodiment, peripheral zone **521** is also substantially adjacent to sagittal surface **515**. Posterior zone **522** substantially covers a region of dense cancellous bone compared to the cancellous bone covered by region **523**. Zones **522** and **523** are in part adjacent to peripheral zone **521**. The density of the cancellous bone of a patient by be determined preoperatively by MRI, CT, DEXA or other know scanning means. Alternately, the density of the bone may be determined interoperatively using a known scanning means, visually by the surgeon or through physical surgeon contact.

FIG. **16** illustrates a top view of an alternate embodiment of a prepared tibial bone **600**. Bone **600** has an anterior end **601**, a posterior end **602**, a sagittal surface **615** and an outer edge **616**. Bone **600** has three tolerance zones: a peripheral zone **621**, a posterior zone **622** and an anterior zone **623**. Peripheral zone **621** extends along outer edge **616** and substantially covers the cortical bone region of bone **600**. Posterior zone **621** substantially covers a region of dense cancellous bone compared to the cancellous bone covered by region **623**. Here, zones **622** and **623** are adjacent to sagittal surface **515**.

In alternate embodiments of tibial bone **500** and bone **600**, any of the previously describe combinations of limitations may be utilized. For example, the relationship of surface area coverage may vary between tolerance zones. Also, the accuracy of tolerance preparation may range from ±0.001 to ±0.100, and include any combination of tolerances therein. In yet alternate embodiments, posterior zone **522** or **622**, may substantially cover an area of dense cancellous bone and be substantially surrounded by a less accurate tolerance zone, **523** or **623** respectively.

In all embodiments described above, there was an anterior zone, outer zone and posterior zone which are held to a more accurate, or "tighter," tolerance than an interior zone. In alternate embodiments, there may be less than three zones held to a more accurate tolerance profile. In yet other embodiments, there may be more than three zones held to a more accurate tolerance profile.

Conventional instruments used in orthopaedic surgeries often include the use of sawblades, punches, and chisels that have many limitations. For example, surgeons often over-prepare or leave sharp corners in bone using these conventional instruments as a result of the dimensions thereof. Further, the geometry of the resected bone using these conventional instruments is generally the result of the skill and accuracy of the surgery.

The following embodiments that will be described herein use a burr tool having a certain diameter and robotic technology to prepare bone with more accuracy and control. Surgeons using these tools will no longer be limited to making planar resections with standard alignment instrumentation or punches and chisels to remove bone. By using a burr tool, the robot can prepare bone to any preoperatively planned shape or intraoperatively desired shape based on the capabilities of the robot. For example, the burr tool can be used to cut radiused edges to a desired tolerance, as opposed to sharp corners that generally result from surgeries using conventional instrumentation.

FIG. **17** is a perspective view of a distal femur **700** having a plurality of planar resections **702**. Such planar resections are generally referred to as distal, anterior, posterior, and anterior and posterior chamfer cuts. A burr having a certain diameter was used to create radiused corners **704**, **706** along inner edges **708** of the resected femur bone. Inner edges **708** with radiused corners **704**, **706** correspond to the dimensions of a box of a posterior-stabilized femoral component. The radius of the radiused corners **704**, **706** substantially match the radius of the finishing cutter that is used to make the resection.

FIG. **18**A is a perspective view of proximal tibia **720** having a resected medial portion **722**. The resected medial

portion **722** preferably houses at least a portion of an implant that is configured to engage an articular surface of a unicondylar or bi-compartmental femoral implant, for example. The resected medial portion has a radiused corner **724** at the intersection of a transverse wall **725** and a sagittal wall **726** adjacent the tibial eminence as shown in FIG. **18**B. Preferably, the radius of the radiused corner **724** substantially matches the radius of the finishing cutter that is used to make the resection.

FIG. **19**A is a perspective view of proximal tibia **740** having a resected medial portion **742**. The resected medial portion has a radiused corner **744** at the intersection of a transverse wall **745** and a sagittal wall **746** adjacent the tibial eminence as shown in FIG. **19**B. Radiused corner **744** runs deeper along sagittal wall **746** than radiused corner **724** shown in FIGS. **18**A-B. The radius of the radiused corner **744** substantially matches the radius of the finishing cutter that is used to make the resection; however, the radius of the radius corner **744** may be larger than the radius of the finishing cutter. In such a case, the finishing cutter may make more than one pass in order to create the dimensions of resected radiused corner **744**.

FIG. **20**A is a perspective view of proximal tibia **760** having a resected portion **762** on medial and lateral sides thereof. Resected portion **762** is formed around the tibial eminence resulting in a tibial plateau **764**. The resected portion has radiused corners **767**, **768** at the intersection of a transverse wall **765** and a sagittal wall **766** adjacent the tibial eminence as shown in FIG. **20**B. The tibial eminence is not resected so as to preserve the anterior and poster cruciate ligaments in a knee arthroplasty procedure. A burr is preferably used to resect a curved recess **770** in the tibial plateau **764**. A portion of a corresponding bicruciate retaining implant is configured to engage and be housed at least partially within curved recess **770**.

For cementless tibial keel preparation, an interference fit between the tibia and the implant is desired to achieve fixation. The level of interference can preferably be customized using a robot. Preferably, the robot will machine a slot in the tibia, into which a tray will be impacted, and the depth and width of the slot can be tailored to achieve a desired level of interference. For example, a keel slot can be prepared to the full depth of a baseplate keel or to a partial depth to achieve greater interference and pressfit if desired.

For cemented tibial keel preparation, surgeons generally want to ensure there is adequate cement mantle around a tibial baseplate to achieve proper fixation. Using the robot, the size of the cement mantle can be customized by tuning in a desired depth and width of a keel slot.

FIGS. **21**A-**24**C show varying prepared keel slot depths in the proximal tibia. The lesser the depth of the keel slot the greater the interference and pressfit there will be on the baseplate keel of tibial prosthesis when the baseplate keel is inserted into the prepared keel slot and into cancellous bone. The depth of keel slot preparation may be defined as the length of the keel slot from a transverse resection on proximal tibia to an end portion thereof within the tibial shaft measured in a superior to inferior direction, for example.

Sclerotic bone may be found at the outskirts of the width of the baseplate keel of the tibial prosthesis approximately 10-14 mm from the transverse resection of the proximal tibia. Preferably, programming of the robot burr should prepare all of this region to get beyond the sclerotic bone. There is a general desire for quick tibial keel preparation and the shallower the keel preparation, the quicker this part of a procedure will be. Further, with shallower keel preparation there are generally less restrictions on the cutter geometry such as heat generation and debris relief, for example.

FIGS. **21**A and **21**B are perspective views of a shallow keel slot **802** in a proximal tibia **800**. Keel slot **802** includes a central portion **804** flanked by two wing portions **806**, **808**. As shown in FIG. **21**C, keel slot **802** is deeper adjacent the ends of the two wing portions **806**, **808** and is shallower in a central region **810**. The deeper portions of keel slot **802** are preferably curved forming curved portions **807**, **809** while the central region **810** is preferably straight. Keel slot **802** is preferably formed by a 2.5 mm burr while a smaller or larger diameter burr may be used. The depth of the keel slot is approximately ¼ the length of the baseplate keel of the tibia prosthesis that will be implanted in and through the keel slot **802**. The depth is measured preferably as a linear distance D1 from the proximal tibia surface **812** to a line tangent to the curved portions **807**, **809** of the keel slot **802**. The max depth of keel slot **802** is preferably 10.2 mm (0.4 in).

FIGS. **22**A and **22**B are perspective views of a deeper keel slot **822** in a proximal tibia **820**. Keel slot **822** includes a central portion **824** flanked by two wing portions **826**, **828**. As shown in FIG. **22**C, keel slot **822** is deeper adjacent the ends of the two wing portions **826**, **828** and is shallower in a central region **830**. The deeper portions of the keel slot are preferably curved forming curved portions **827**, **829** while the central region **830** is preferably straight. Central region **830** is more prominent that central region **810** of keel slot **802**. Keel slot **822** is preferably formed by a 2.5 mm burr while a smaller or larger diameter burr may be used. The depth of keel slot **822** is approximately ½ the length of the baseplate keel of the tibia prosthesis that will be implanted in and through the keel slot **822**. The depth is measured preferably as a linear distance D2 from the proximal tibia surface **822** to a line tangent to the curved portions **827**, **829** of the keel slot **822**. The max depth of keel slot **822** is preferably 14 mm (0.55 in).

FIGS. **23**A and **23**B are perspective views of an even deeper keel slot **842** in a proximal tibia **840**. Keel slot **842** includes a central portion **844** flanked by two wing portions **846**, **848**. As shown in FIG. **23**C, keel slot **842** is shallower adjacent the ends of the two wing portions **846**, **848** and is deeper in a central region **850**. The shallower portions of keel slot **842** are preferably curved forming curved portions **847**, **849** as well as central region **850**. Central region **850** is preferably formed with a lead-in central opening. Keel slot **842** is preferably formed by a 2.5 mm burr while a smaller or larger diameter burr may be used. The depth of keel slot **842** is approximately ¾ the length of the baseplate keel of the tibia prosthesis that will be implanted in and through the keel slot **842**. The depth is measured preferably as a linear distance D3 from the proximal tibia surface **842** to a line tangent to the central region **850** of the keel slot **842**. The max depth of keel **842** is preferably 23 mm (0.9 in).

FIGS. **24**A and **24**B are perspective views of an even deeper keel slot **862** in a proximal tibia **860** that the keel slot **842** in proximal tibia **840**. Keel slot **862** includes a central portion **864** flanked by two wing portions **866**, **868**. As shown in FIG. **24**C, keel slot **862** is shallower adjacent the ends of the two wing portions **866**, **868** and is deeper in a central region **870**. The shallower portions of keel slot **862** are preferably curved forming curved portions **867**, **869** as well as central region **870**. Keel slot **862** is preferably formed by a 2.5 mm burr while a smaller or larger diameter burr may be used. The depth of keel slot **862** is approximately the full length of the baseplate keel of the tibia prosthesis that will be implanted in and through the keel slot **862**. The depth is measured preferably as a linear distance

D4 from the proximal tibia surface **862** to a line tangent to the central region **870** of the keel slot **862**. The max depth of keel slot **862** is preferably 33.5 mm (1.32 in).

FIG. **25**A is a plan view of one embodiment of a keel punch **900**. Keel punch **900** includes a head portion **902**, a shaft portion **904** and a punch portion **906**. A distal portion **908** of punch portion **906** is received in a prepared keel slot through the proximal tibia and into cancellous bone until a proximal portion **910** of punch portion **906** is approximately 0.09" from a resected transverse surface on the proximal tibia. A central longitudinal axis of shaft portion **904** is preferably angled 1° from a central longitudinal axis of punch portion **906**.

The cross-section of punch portion **900** as shown in section **2-2** of FIG. **25**B is substantially similar to the keel slots shown in FIG. **21**A-**24**C. Punch portion **906** includes a central portion **912** flanked by two wing portions **914**, **916**. As shown in FIG. **25**B, the cross-section of punch portion **900** shows striations **918** of punch portion **906** adjacent the proximal portion **910** of punch portion **906**. Punch portion **906** includes a plurality of striations **918** which are peak portions along the cross-section of the wing portions **914**, **916** of punch portion **906**. The plurality of striations **918** are flanked by valley portions **920**. Striations **918** are configured to form an interference fit with the bone of the proximal tibia while valley portions **920** are configured to form relief portions that may either be clearance or interference portions.

A traditional keel punch as shown in FIG. **25**A, for example, leaves a keel slot adjacent the transverse surface of the proximal tibia having a cross-section generally as shown in FIG. **25**B, for example. The cross-section as shown in FIG. **25**B may be modified using a burr having a particular diameter following a particular tool path. The following embodiments discuss the different levels of clearance and interference between certain burr sizes and tool paths used to create a keel slot in the proximal tibia.

FIG. **26**A is an example of a cross-section **1000** of a punch portion of a keel punch adjacent the proximal end of the punch portion. FIG. **26**B shows the difference in cross-section between a 3 mm burr straight cut **1010** and the cross-section **1000** of a portion of the punch portion of the keel punch shown in FIG. **26**A. The 3 mm burr straight cut **1010** provides approximately 0.0035" clearance with a tibial prosthesis, which provides less interferences with the tibial prosthesis compared to conventional tibial resection using the keel punch. FIG. **26**C shows the difference in cross-section between a 3 mm burr wave cut **1020** and the cross-section **1000** of a portion of the punch portion of the keel punch shown in FIG. **26**A. The 3 mm burr wave cut **1020** follows the direction of the arrows in alternating posterior and anterior directions. The 3 mm burr wave **1020** cut provides approximately 0.011" clearances and 0.004" interferences at a minimum with the tibial prosthesis, which provides greater clearances and lesser interferences with the tibial prosthesis compared to 3 mm burr straight cut **1010** shown in FIG. **26**B.

FIG. **27**A is an example of a cross-section **1100** of a punch portion of a keel punch adjacent the proximal end of the punch portion. FIG. **27**A also shows a 2.5 mm burr straight cut **1110** overlay on cross-section **1100**. The punch portion of the keel punch shown includes a plurality of alternating major striations **1102** and minor striations **1104** and the interference and clearance differences at the locations of the major and minor striations in relation to a conventional keel punch. As explained above, major and minor striations **1102**, **1104** are alternating peaks and valley portions, respectively. Major striations **1102** are portions on the punch portion of the keel punch that provide relatively greater interference with a corresponding keel of a tibial prosthesis than are provided by minor striations **1104**, if at all. For instance, major striations **1102** generally provide interference with a corresponding keel of a tibial prosthesis, while minor striations **1104** generally provide no interference, but instead provide clearance with a corresponding keel of a tibial prosthesis.

As shown in FIG. **27**B, there is a cross-sectional view at Section **1-1** of FIG. **27**A of the 2.5 mm burr straight cut **1110** in relation to the major striation **1102** of the conventional keel punch. There is an added 0.007" interference difference created with the 2.5 mm burr straight cut **1110** in relation to the interference created by the major striation **1102** of the conventional keel punch at Section **1-1**. Using the 2.5 mm burr straight cut **1110**, there will result in greater interferences with the keel of the tibial prosthesis at the major striations thereof compared to the resulting interferences created with convention keel punch preparation. FIG. **27**C there is a cross-sectional view at Section **2-2** of FIG. **27**A of the 2.5 mm burr straight cut **1110** in relation to the minor striation **1104** of the conventional keel punch. As shown, there is a 0.012" clearance difference created between the 2.5 mm burr straight cut **1110** in relation to the clearance created by the minor striation **1104** of the conventional keel punch at Section **2-2**. Using the 2.5 mm burr straight cut **1110**, there will result in lesser clearances (i.e. greater interferences) with the keel of the tibial prosthesis at the minor striations thereof compared to the resulting clearances created with conventional keel punch preparation.

FIG. **28**A is an example of a transverse cross-section **1200** of a tibial prosthesis keel **1220**, a punch portion **1240** of a keel punch, and a 2.5 mm burr wave cut **1260**. FIG. **28**A shows the differences in interferences and clearances created between each of the punch portion **1240** and 2.5 mm burr wave cut **1260** in relation to the tibial prosthesis keel **1220**. FIG. **28**B shows that the 2.5 mm burr wave cut **1260** results in alternating 0.014" and 0.028" interferences between alternating peaks **1264** and valleys **1262** of the 2.5 mm burr wave cut **1260**, respectively, in relation to alternating major striations **1224** of the tibial prosthesis keel **1220**. Further, the 2.5 mm burr wave cut **1260** results in less than a 0.002" interference between an intermediate portion **1263** of the 2.5 mm burr wave cut **1260** located between the alternating peaks **1264** and valleys **1262** thereof and the minor striations **1224** of the tibial prosthesis keel **1220**.

FIG. **29**A is an example of a transverse cross-section **1300** of a tibial prosthesis keel **1320**, a punch portion **1340** of a keel punch, and a 2.0 mm burr wave cut **1360**. FIG. **29**A shows the differences in interferences and clearances created between each of the punch portion **1340** and 2.0 mm burr wave cut **1360** in relation to the tibial prosthesis keel **1320**. FIG. **29**B shows that the 2.0 mm burr wave cut **1360** results in alternating 0.014" and 0.048" interferences between alternating peaks **1364** and valleys **1362** of the 2.0 mm burr wave cut **1360**, respectively, in relation to alternating major striations **1324** of the tibial prosthesis keel **1320**. Further, the 2.0 mm burr wave cut **1360** results in less than a 0.002" interference between an intermediate portion **1363** of the 2.0 mm burr wave cut **1360** located between the alternating peaks **1364** and valleys **1362** thereof and the minor striations **1324** of the tibial prosthesis keel **1320**.

FIG. **30**A is an example of a transverse cross-section **1400** of a tibial prosthesis keel **1420**, a punch portion **1440** of a keel punch, and a 2.0 mm burr double wave cut **1460** including a first wave cut **1461** and a second wave cut **1463**.

First and second wave cuts **1461**, **1463** travel along the length of each cut in alternating anterior and posterior directions. FIG. **30**A shows the differences in interferences and clearances created between each of the punch portion **1440** and 2.0 mm burr double wave cut **1460** in relation to the tibial prosthesis keel **1420**. FIG. **30**B shows that the 2.0 mm burr double wave cut **1460** results in alternating 0.014" and 0.012" interferences between alternating peaks **1464** and valleys **1462** of the 2.0 mm burr double wave cut **1460**, respectively, in relation to alternating major striations **1424** and minor striations **1422** of the tibial prosthesis keel **1420**, respectively.

FIG. **31**A is an example of a transverse cross-section **1500** of a tibial prosthesis keel **1520**, a punch portion **1540** of a keel punch, and successive 2.5 mm burr plunge cuts **1560** located at each major striation **1524** of tibial prosthesis keel **1520** and a 1.5 mm burr straight cut **1580**. FIG. **31**A shows the differences in interferences and clearances created between each of the punch portion **1540** and successive 2.5 mm burr plunge cuts **1560** located at each major striation **1524** of tibial prosthesis keel **1520** and a 1.5 mm burr straight cut **1580** in relation to the tibial prosthesis keel **1520**. FIG. **31**B shows that the successive 2.5 mm burr plunge cuts **1560** located at each major striation **1524** of tibial prosthesis keel **1520** result in a 0.021" interference with each major striation **1524** of tibial prosthesis keel **1520**. Also shown in FIG. **31**B is that at each minor striation **1522** of tibial prosthesis keel **1520** there is a 0.023" interference with the 1.5 mm burr straight cut **1580**.

FIG. **32**A is an example of a transverse cross-section **1600** of a tibial prosthesis keel **1620**, a punch portion **1640** of a keel punch, and successive 2.5 mm burr plunge and drag cuts **1660**. A central axis of the plunge of the 2.5 mm burr is preferably located adjacent an intermediate portion **1623** thereof located between an adjacent minor striation **1622** and major striation **1624** of the tibial prosthesis keel **1620**. The length of the drag of the 2.5 mm burr in a medial to lateral direction (or vice versa depending on whether the left or right tibia is being resected) is the distance between adjacent intermediate portions **1623** along the length of the tibial prosthesis keel **1620**. FIG. **31**A shows the differences in interferences and clearances created between each of the successive 2.5 mm burr plunge and drag cuts **1660** in relation to the tibial prosthesis keel **1520**. FIG. **32**B shows that the maximum interference between the minimum striation **1662** created between successive 2.5 mm burr plunge and drag cuts **1660** and the minor striation **1622** of the tibial prosthesis keel **1620** is 0.052" (depending on amount of plunge overlap between successive 2.5 mm burr plunge and drag cuts **1660**). FIG. **32**C shows that the minimum interference between the maximum striation **1664** created between successive 2.5 mm burr plunge and drag cuts **1660** and the maximum striation **1624** of the tibial prosthesis keel **1620** is 0.021".

FIG. **33**A is an example of a transverse cross-section **1700** of a tibial prosthesis keel **1720**, a punch portion **1740** of a keel punch, and successive 2.5 mm burr plunge cuts **1760**. A central axis of each of the successive 2.5 mm burr plunge cuts **1760** is preferably located adjacent an intermediate portion **1723** located between an adjacent minor striation **1722** and major striation **1724** of the tibial prosthesis keel **1720**. Successive central axes of 2.5 mm burr plunge cuts **1760** are preferably at least 0.065" apart from one another. FIG. **33**A shows the differences in interferences and clearances created between each of the punch portion **1740** and successive 2.5 mm burr plunge cuts **1760** in relation to the tibial prosthesis keel **1720**. FIG. **33**B shows that the successive 2.5 mm burr plunge cuts **1760** located at a major striation **1724** of tibial prosthesis keel **1720** results in a maximum 0.037" interference with a minor striation **1764** of the successive 2.5 mm burr plunge cuts **1760**. Also shown in FIG. **33**B is that minor striations **1722** of tibial prosthesis keel **1720** there is a minimum 0.003" interference with a major striation **1762** of the successive 2.5 mm burr plunge cuts **1760**.

FIG. **34**A is an example of a transverse cross-section **1800** of a tibial prosthesis keel **1820**, a punch portion **1840** of a keel punch, and successive 2.0 mm burr plunge cuts **1860**. A central axis of each of the successive 2.0 mm burr plunge cuts **1860** is preferably located adjacent an intermediate portion **1823** located between an adjacent minor striation **1822** and major striation **1824** of the tibial prosthesis keel **1820**. Successive central axes of 2.0 mm burr plunge cuts **1860** are preferably at least 0.030" apart from one another. FIG. **34**A shows the differences in interferences and clearances created between each of the punch portion **1840** and successive 2.0 mm burr plunge cuts **1860** in relation to the tibial prosthesis keel **1820**. FIG. **34**B shows that the successive 2.0 mm burr plunge cuts **1860** located at a major striation **1824** of tibial prosthesis keel **1820** results in a maximum 0.055" interference with a minor striation **1864** of the successive 2.0 mm burr plunge cuts **1860**. Also shown in FIG. **34**B is that minor striations **1822** of tibial prosthesis keel **1820** there is a minimum 0.013" interference with a major striation **1862** of the successive 2.0 mm burr plunge cuts **1860**.

FIG. **35**A is an example of a transverse cross-section **1900** of a tibial prosthesis keel **1920**, a punch portion **1940** of a keel punch, and successive 2.0 mm burr plunge diamond cuts **1960** including first, second, third and forth plunge cuts **1966**, **1967**, **1968** and **1969**, respectively. A central axis of first plunge cut **1966** of the 2.0 mm burr for each diamond cut is preferably located adjacent an intermediate portion **1923** located between an adjacent minor striation **1922** and major striation **1924** of the tibial prosthesis keel **1920**. The second, third and forth plunge cuts are then created in a clockwise or counterclockwise fashion from first plunge cut **1966**. FIGS. **35**B and **35**C show the differences in interferences and clearances created between each of the successive 2.0 mm burr plunge diamond cuts **1960** in relation to the tibial prosthesis keel **1620**. FIG. **35**B shows that the maximum interference between the minimum striation **1962** created between successive 2.0 mm burr plunge diamond cuts **1960** and the minor striation **1922** of the tibial prosthesis keel **1920** is 0.052" (depending on amount of plunge overlap between successive 2.0 mm burr plunge diamond cuts **1960**). FIG. **35**C shows that the minimum interference between the maximum striation **1964** created between successive 2.0 mm burr plunge diamond cuts **1960** and the maximum striation **1924** of the tibial prosthesis keel **1920** is 0.013".

FIG. **36**A is a perspective view of a punch portion **2040** of a keel punch with successive 2.5 mm drilled holes **2060** and 2.0 mm burr plunge cuts **2070** in between each 2.5 mm drilled holes **2060** following the path of an outer perimeter surface **2042** of the punch portion. The depth of the 2 mm burr plunge cuts **2070** preferably are at a constant offset of approximately 8 mm from the outer perimeter surface **2042** of the punch portion. This offset allows for bone compression and interference when a tibial prosthesis keel **2020** is fully received in the prepared resection using this multi-cut strategy. FIG. **36**B is an example of a transverse cross-section **2000** of the tibial prosthesis keel **2020**, the punch portion **2040** of the keel punch, and the 2.5 mm drilled holes

2060 and 2.0 mm burr plunge cuts 2070 in between each 2.5 mm drilled holes 2060. A central axis of each of the successive 2.5 mm drilled holes 2060 is preferably located adjacent a major striation 2024 of the tibial prosthesis keel 2020. FIG. 36C shows that the successive 2.5 mm drilled holes 2060 located adjacent major striations 2024 of tibial prosthesis keel 2020 result in approximately 0.021" interference with a major striation 2064 of the successive 2.5 mm drilled holes 2060. Also shown in FIG. 36B is that minor striations 2022 of tibial prosthesis keel 2020 there is approximately 0.013" interference created between a minor striation 2062 of the 2 mm burr plunge cuts 2060.

FIG. 37A is a perspective view of a punch portion 2140 of a keel punch with successive 2.5 mm drill pivot cuts 2160 following the path of an outer perimeter surface 2142 of the punch portion. The 2.5 mm drill shown in FIG. 37B removes material in the proximal tibia by pivoting on a point fixed at a distal end of the desired depth following what would be the outer perimeter surface 2142 of the punch portion. Each pivot cut includes three separate plunge cuts having an axis approximately 10° from each successive plunge. Each successive plunge cut can be more or less than 10° depending on the interference desired between the resection created and a corresponding tibial prosthesis keel such as prosthesis keel 2120. FIG. 37C is an example of a transverse cross-section 2100 of the tibial prosthesis keel 2120, the punch portion 2140 of the keel punch, and the 2.5 mm drill pivot cuts 2160. As shown in FIGS. 37C-D, a central axis of each pivot cut 2160 is preferably located adjacent a major striation 2124 of the tibial prosthesis keel 2120. FIG. 37D shows that the successive 2.5 mm drill pivot cuts 2160 located adjacent major striations 2124 of tibial prosthesis keel 2120 result in approximately 0.021" interference with a major striation 2164 of the successive 2.5 mm drill pivot cuts 2160. Also shown in FIG. 37D is that there is approximately 0.045" interference created between a minor striation 2162 of the successive 2.5 mm drill pivot cuts 2160 and minor striations 2122 of tibial prosthesis keel 2120.

FIG. 38A is a perspective view of an embodiment of a tibial prosthesis keel 2220 having a custom keel shape around a portion of an outer perimeter 2222 thereof. FIG. 38B is an embodiment of a 0.5° drafted end mill 2240. The custom keel shape shown in FIG. 38A can be prepared using multiple plunge cuts with end mill 2240. Leading edge cuts are made using end mill 2240 while following shape of outer perimeter 2222 of tibial prosthesis keel 2220. Such cuts will compress cancellous bone for receipt of tibial prosthesis keel 2220 creating a greater compression fit.

Prior to finishing off certain bone cuts with an accurate cut using a burr and robot, for example, debulking is generally performed to remove a majority of bone as a first pass before such a finishing pass is performed. While debulking is performed to remove a majority of bone, a sufficient amount of bone must be preserved such that subsequent adjustments to all degrees of freedom of an implant that will be implanted on the resected surface can still be done. In a finishing pass, 1-2 mm layer of remaining bone on all cut surfaces is removed. Final adjustments to implant position and shape is made during a finishing pass. This may include a scalloped surface finish for receipt of certain shaped implants.

FIGS. 39A and 39B are perspective views of the proximal tibia 2300 after bicruciate retaining debulking and finishing is performed. As shown there is an outer tool boundary region 2320, a cortical rim region 2340 and a cancellous bone region 2360. These regions may vary in size depending on the diameter of the debulking cutter used. For example, a 3, 4 or 5 mm diameter debulking cutter may be used to create the debulking cutter radius all around the proximal tibia as shown in tool boundary region 2320. Preferably, a 3.2 mm burr is used to create a finishing cutter radius 2380 formed around the eminence. As shown in FIG. 39C, there is a dotted line 2330 in which a 3.2 mm burr is used for machining a keel 2352 and pegs 2354 for a tibial baseplate 2350.

For peg preparation, an interference fit between the bone and the implant is often desired to achieve adequate fixation. With the robot, this level of interference can be customized. The robot will machine away an opening in the bone into which the implant will be impacted, and the diameter of the opening can be tailored to achieve a desired level of interference. For example, a smaller peg hole diameter can be prepared to achieve greater interference between the bone and the implant.

FIGS. 40, 41 and 42 are perspective views of the distal femur after debulking and finishing is performed. As shown in FIG. 40, distal femur 2400 includes an outer tool boundary region 2420, a cortical rim region 2440 and a cancellous bone region 2460. A portion of outer tool boundary region 2420 bounds a cruciate retaining region 2480. As shown in FIG. 41, distal femur 2500 includes an outer tool boundary region 2520, a cortical rim region 2540 and a cancellous bone region 2560. A portion of outer tool boundary region 2520 bounds a posterior stabilization region 2580. As shown in FIG. 42, distal femur 2600 includes a partial knee resurfacing region having an outer tool boundary region 2620, a cortical rim region 2640 and a cancellous bone region 2660. A region 2680 is shown where a finishing cutter is used to minimize the resultant gap between implant and cartilage. FIG. 43A is a side view and FIG. 43B is a plan view of a unicondylar prosthesis 2700 on the partial knee resurfacing region of FIG. 42.

Traditionally, an interference fit is created between the pegs on the implant and the peg preparation in the bone for cementless femoral total knee arthroplasty ("TKA") procedures. Additionally, interference can be created between the implant and the anterior and posterior bone resections. The following embodiments discuss bone preparation methods intended to create additional press-fit between a cementless femoral TKA and the prepared bone. An interference press fit is created between the implant and the bone by preparing the bone with a rib-like pattern on the anterior bone cut surface. The ribs are intended to compact upon impaction of the femoral component. Preferably, the ribs extend along the most anterior bone cut surface, and run distal to posterior, parallel to the intended anterior bone cut surface of the implant.

As shown in FIG. 44A, distal femur 2700 includes a tolerance profile or ribs 2720 extending along an anterior bone cut surface. When an implant is introduced onto the bone, the ribs 2720 compact and achieve an interference fit between the implant and the bone. FIG. 44B shows a cross-sectional view of ribs 2720 of FIG. 44A. The three-dimensional geometry of ribs 2720 is the result of a rotational cutting tool, such as a burr for example, making a plurality of channeled preparations 2722 into distal femur 2700. In the embodiment shown, the plurality of channeled preparations 2722 follow a substantially linear path. Ribs 2720 have a height 2724, a width 2726 and a plurality of protrusions 2728. Ribs 2720 shown on distal femur 2700 are similar to the tolerance profile 30 shown in FIGS. 3 and 4, for example. In this embodiment, the radius of the finishing burr is preferably 2.5-3.5 mm.

As shown in FIG. **45**, distal femur **2800** includes an MMC implant profile. The peak-to-peak distance between adjacent ribs **2820** can be adjusted to have more or less interference press fit and compaction. Width **2826** of ribs **2820** is defined as the distance from bone peak **2882** to adjacent peak in a transverse direction.

FIG. **46** shows distal femur **2900** including a LMC implant profile. The bone will be compacted approximately 0.01" upon implantation of the LMC implant. This compaction is shown as the linear distance between a first line adjacent bone peak **2982** and a second line closer to valley **2984**.

In other embodiments, this concept of highly toleranced zones of bone preparation may be used for other bone preparation and prosthetic implants throughout the body. Other areas and uses may include bicompartmental knee replacement implants, tricompartmental knee replacement implants, total knee replacement implants, patellofemoral replacement implants, acetabular cup implants, spinal interbody devices, and vertebral body replacements.

The invention claimed is:

1. A method of preparing a bone surface to receive a prosthetic implant thereon, the prosthetic implant having an articular surface and a bone contacting surface, the method comprising:

resecting the bone surface at a first location to create a first resected region having a first tolerance profile with a first cross-section having peaks and valleys;

resecting the bone surface at a second location to create a second resected region having a second tolerance profile with a second cross-section less dense than the first cross-section such that the second cross-section has peaks further apart and valleys deeper than the peaks and valleys of the first cross-section; and

contacting the bone contacting surface of the prosthetic implant with the first resected region.

2. The method of claim **1**, further comprising:

forming at least one recess in the bone surface prior to implanting the prosthetic implant on the bone surface; and

inserting a retention element extending from the bone contacting surface in the at least one recess in the bone surface.

3. The method of claim **2**, including applying downward force to the articular surface of the prosthetic implant to compact bone in the first resected region.

4. The method of claim **1**, further comprising:

resecting the bone surface at a plurality of locations to create a plurality of resected regions each having a tolerance profile with a cross-section, wherein the tolerance profile of each of the plurality of resected regions is denser than the cross-section of the second tolerance profile.

5. The method of claim **4**, wherein the tolerance profile of the second resected region is ±0.010 inches and the tolerance profile of the plurality of resected regions is ±0.025 inches.

6. The method of claim **4**, wherein a first of the plurality of resected regions is located at an anterior aspect of the bone surface.

7. The method of claim **6**, wherein a second of the plurality of resected regions is located at an outer aspect of the bone surface.

8. The method of claim **7**, wherein a third of the plurality of resected regions is located at a posterior aspect of the bone surface.

9. The method of claim **8**, wherein the cross-section of the tolerance profile of the first of the plurality of resected regions is less dense than the cross-section of the tolerance profile of the second of the plurality of resected regions and is more dense than the cross-section of the tolerance profile of the third of the plurality of resected regions.

10. A method of preparing a bone surface to receive a prosthetic implant thereon, the prosthetic implant having an articular surface and a bone contacting surface, the method comprising:

resecting the bone surface at an anterior aspect thereof to create a first resected region having a first tolerance profile with a first cross-section having peaks and valleys;

resecting the bone surface at a posterior aspect thereof to create a second resected region having a second tolerance profile with a second cross-section having peaks further apart and valleys deeper than the peaks and valleys of the first cross-section such that the first cross-section is denser than the second cross-section; and

contacting the bone contacting surface of the prosthetic implant with the first resected region.

11. The method of claim **10**, further comprising:

forming at least one recess in the bone surface prior to implanting the prosthetic implant on the bone surface; and

inserting a retention element extending from the bone contacting surface in the at least one recess in the bone surface.

12. The method of claim **11**, including applying downward force to the articular surface of the prosthetic implant to compact bone in the first resected region.

13. The method of claim **10**, further comprising:

resecting the bone surface at a plurality of locations to create a plurality of resected regions each having a tolerance profile with a cross-section, wherein the tolerance profile of each of the plurality of resected regions is denser that the cross-section of the second tolerance profile.

14. The method of claim **13**, wherein the tolerance profile of the second resected region is ±0.010 inches and the tolerance profile of the plurality of resected regions is ±0.025 inches.

15. A method of preparing a bone surface to receive a prosthetic implant thereon, the prosthetic implant having an articular surface and a bone contacting surface, the method comprising:

resecting the bone surface at a peripheral region thereof to create a first resected region having a first tolerance profile with a first cross-section having peaks and valleys;

resecting the bone surface at an anterior region thereof to create a second resected region having a second tolerance profile with a second cross-section having peaks further apart and valleys deeper than the peaks and valleys of the first cross-section such that the first cross-section is denser than the second cross-section; and

contacting the bone contacting surface of the prosthetic implant with the first resected region.

16. The method of claim **15**, further comprising:

forming at least one recess in the bone surface prior to implanting the prosthetic implant on the bone surface; and

inserting a retention element extending from the bone contacting surface in the at least one recess in the bone surface.

17. The method of claim 16, including applying downward force to the articular surface of the prosthetic implant to compact bone in the first resected region.

18. The method of claim 15, further comprising:

resecting the bone surface at a plurality of locations to create a plurality of resected regions each having a tolerance profile with a cross-section, wherein the tolerance profile of each of the plurality of resected regions is denser than the cross-section of the second tolerance profile.

19. The method of claim 18, wherein the tolerance profile of the second resected region is ±0.010 inches and the tolerance profile of the plurality of resected regions is ±0.025 inches.

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